HOW TO BUILD

Dynamo-Electric Machinery

EMBRACING THEORY DESIGNING AND THE CONSTRUCTION OF DYNAMOS AND MOTORS.

By Edward Trevert.

With Appendices on Field Magnet and Armature Winding. Management of Dynamos and Motors, and Useful Tables of Wire Gauges.

ILLUSTRATED.

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PREFACE.

Almost the first piece ot electrical apparatus the student wishes to construct is the dynamo, in fact it is important that he should be familiar with this machine at the beginning of his studies in electricity. It is the purpose of this book to give practical directions for building small dynamos and motors, and these directions are accompanied with working drawings which will enable the reader to understand the text more clearly. The machines described have been carefully selected both for efficiency and beauty of form. They are easy to build, the design of castings being for as few pieces as possible.

This book is intended as a practical treatise, and in no way is it to be considered as technical. Some theory, however, is given to help the reader in a general way. The chapters on commercial dynamos and motors are added to show the general construction of large machines. The chapter on management, and the one containing useful tables, the author hopes will add to the value of the book. No foreign dynamos or motors have been described, owing to the fact that there is sufficient material for description in American machines to answer every purpose of this work.

EDWARD TREVERT.

LYNN, MASS., JUNE 30, 1894.

PREFACE TO SECOND EDITION.

Eight years having passed away since this book was first published, the publishers have requested me to make some additions and bring it up to date. This I have done, and trust that my effort will prove satisfactory to the reader.

EDWARD TREVERT.

LYNN, MASS., 1902.

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HOW TO BUILD
Dynamo-Electric Machinery.

CHAPTER I.

HISTORICAL NOTES.

FARADAY, in 1831, made the discovery of what is termed Magneto-Electric Induction of Currents. He showed that induced currents of electricity could be produced in a closed coil of wire, by means of currents started or stopped in a neighboring coil. He also induced electric currents in a coil moved in front of the poles of a powerful steel magnet. These experiments showed the first principles of all dynamo-electric machinery. About this time he also constructed his first magneto-electric machine. "*It consisted of a disc of copper 12 inches in diameter and about one-fifth of an inch in thickness, fixed upon a brass axle. It was mounted in frames so as to allow of revolution, its edge being at the same time introduced between the poles of a large compound permanent magnet, the poles being about half an inch apart." "† The edge of the plate was well amalgamated, for the purpose of obtaining a good but movable contact, and a part around the axle was also prepared in a similar manner. Conducting strips of copper and lead to serve as electric collectors, were prepared so as to be placed in contact with the edge of the copper disc; one of these was held by hand to touch the edge of the disc between

* Thompson's "Dynamo-Electric Machinery." † Faraday's Experimental Researches.

the magnet poles. The wires from a galvanometer were connected; the one to the collecting-strip, the other to the brass axle; then on revolving the disc, a deflection of the galvanometer was obtained, which was reversed in direction when the direction of the rotation was reversed. "Here, therefore, was demonstrated the production of a permanent current of electricity by ordinary magnets."

All the early dynamos were made with permanent field magnets, the armature being soft iron cores with spools of wire placed over them. These machines gave an alternating current.

*In 1841 "Wheatstone produced the first continuous current machine. This machine had five armatures, each consisting of a pair of short parallel cylindrical coils with iron cores, and each having a simple split tube commutator. These armatures were arranged in a row along a single shaft with six compound steel magnets between them. The five armatures being so set that they came successively into the position of the greatest activity, no two of them being commuted at the same instant. They were connected in series with one another by wires, which joined the positive brush—a brass spring—of one to the negative brush of the next."

Four years later, 1845, Wheatstone and Cooke patented the use of electro-magnets instead of permanent steel magnets in such machines.

In 1848, Jacob Brett made the important suggestion of causing the current developed in the armature by the permanent magnetism of the field magnets to be transmitted through a coil of wire surrounding the magnet, so as to increase its action. This appears to be the first suggestion of the principle of the self-exciting dynamo.

* Thompson's "Dynamo Electric Machinery."

In 1856, C. W. Siemens provisionally patented the shuttle-wound longitudinal armature, invented by Werner Siemens.

In 1866 and 1867 Wilde produced alternating current machines. The latest had a number of bobbins mounted on the periphery of a disc rotating between two opposite crowns of alternately polarized field magnets. This type survives to the present day.

In 1864, Pacinotti devised a machine with a ring armature, the core consisting of a toothed iron wheel between the teeth of which the coils were wound in sixteen separate sections.

In 1870, Gramme invented a ring armature without teeth; the principle of which was winding a continuous coil in separate symmetrical sections around a ring, or other figure of revolution, until it was entirely overwound with wire. By winding an armature with a number of such symmetrically grouped coils, which pass successively through the magnetic field, currents can be obtained that are practically steady. In 1880, Elihu Thomson and E. J. Houston invented a unique dynamo, having cup-shaped field-magnets and a spherical armature wound with three coils. Since 1883, large multipolar dynamos have been invented by Siemens, Halske, and others. Large alternating current machines have also been placed upon the market by the Westinghouse Company, General Electric Company, and others.

The first electric motor in the true sense of the word may be said to be Barlow's rotating wheel. This he produced in 1823. Barlow discovered that by passing an electric current from the centre to the circumference of a copper disc placed between the poles of a powerful magnet, the disc would revolve. The current was sent perpendicularly through the disc from its axis to its circumference, when it passed into a cup of mercury.

was simply the reverse of Faraday's experiment. Various motors of more or less importance were invented after this date by Abbe Salvatore, Dal Negro, Jacobi, Froment, Du Moncel and others. In 1837 Thomas Davenport, a blacksmith of Brandon, Vt., patented the first electric motor ever invented in the United States. Among other early inventors of this country were Page and Vergnes. The reversibility of the dynamo is claimed to have been discovered by Siemens in 1867. It was put into practical application in 1873 at the Vienna Exposition by Hippolite, Fontaine, and Bregnet. In this case a Gramme dynamo machine was used as a motor, the current being supplied by a similar machine, the machine being driven by a gas engine. Improvements have been steadily going on up to the present time, and we now have the inventions of Edison, Thomson, Sprague, Tesla and others.

CHAPTER II.

PRINCIPLES OF DYNAMO-MACHINES.

A DYNAMO is a machine for generating electricity by mechanical means. All dynamos are capable of serving two distinct functions. They may be used to generate electricity by mechanical force, as when the machine is driven by a steam engine or a water wheel, or they may be run as motors and develop mechanical power, as when supplied by an electric current from another dynamo or a voltaic battery.

All dynamo-machines have a field magnet and an armature. The function of the field magnet is to furnish a magnetic field in which the armature revolves.

The function of the armature is to revolve within the magnetic field, thereby cutting the lines of force while carrying the electric currents in its coils or conductors.

*"It must be remembered that there is a two-fold action between a conducting wire (forming part of a circuit) and a magnetic field: *Firstly*, if the conducting wire is forcibly moved across the magnetic field (so as to cut the magnetic lines), electric currents are generated in the conductor, and a mechanical effort is required to move the conductor. This action, discovered by Faraday, is termed 'magneto-electric induction.' In every case the induction or generation of currents necessitates the applica-

* S. P. Thompson, "Dynamo-Electric Machinery."

tion of mechanical power and the expenditure of energy. This is the principle of the dynamo used as a generator. *Secondly*, if the conducting wire, while situated in the magnetic field, is actually conveying an electric current (from whatever source) it experiences a lateral thrust, tending to move it forcibly, parallel to itself, across the magnetic lines, and so enables it to exert power, and to do work. This action, which is the converse of the former, is the principle of the dynamo when used as a motor. In the first case, power is required to drive the armature; in the second, the armature rotating becomes a source of power. If we have the magnetic field, and supply power to drive the rotating conductor, we get the electric currents; if we have the magnetic field and supply the electric currents to the conductor, it rotates and furnishes power. Whether the machine be used as a generator or a motor, the magnetic field must be present: hence the most important theory is the theory of the magnetic field." As theoretically, every dynamo may be worked either as a generator or a motor, the reader should be able to frame a general theory for any machine serving either of the two converse functions. All dynamos are based on the principle of Faraday's discovery,—that electric currents are generated in conductors by moving them in a magnetic field, and with dynamos this field is produced by field magnets. All magnets are surrounded by what is known as the field of force. The familiar experiments with the magnet and iron filings give us some idea of the character of this field, for the filings always adjust themselves along certain lines, generally curves, depending for their shape upon the form of the magnet. If a bar magnet is used in this experiment the iron filings will be found to have arranged themselves into lines as shown in Figure 1.

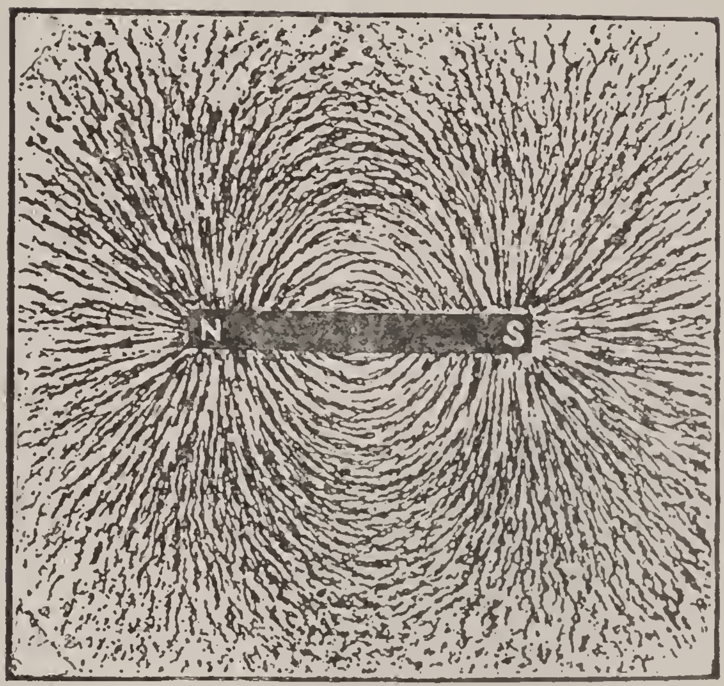


FIGURE 1.

If the experiment is made by dusting the iron filings into the field of one end or pole of a bar magnet the lines will be found as shown in Figure 2.

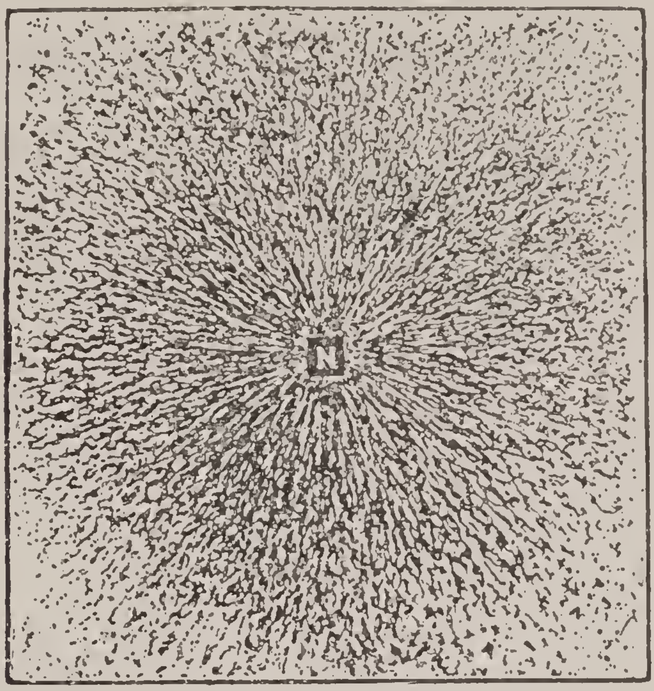


FIGURE 2.

Thus we see that the region surrounding the magnet is conceived as being penetrated by "lines of force," which radi-

ate from the poles and are parallel to the lines of iron filings. They emerge from the magnet something like the bristles of a brush and always form closed curves, that is, they always return by longer or shorter routes to the body of the magnet and through it to the starting point. It is for this reason that it is impossible to make an unipolar magnet. Every magnet must have two poles, a north and south. These lines do not pass with equal facility through all substances. Most bodies offer a high resistance to them, but iron, steel and nickel, are good magnetic conductors. Magnetism always follows the path of least resistance, and with a given magnetizing force; the intensity of the resulting magnetism is enormously increased by the presence of iron. It is for this reason that iron is used in the field magnets of dynamos and motors, and it is of the greatest importance that the magnetic circuit or path over which the magnetic force passes shall have a large cross section and a low resistance.

Whenever a conductor of electricity is passed through the field of force surrounding a magnet, at right angles to the lines, an electro-motive force is set up in it, depending upon the length of the conductor, the speed at which it moves, and the intensity of the field. This fact is the one utilized in the construction of dynamos and forms the basis of our calculations, for, knowing the strength of the field magnets, the length of wire on the armature, and the speed at which it revolves, we have all the data necessary to calculate our electromotive force.

The simplest form of armature is the shuttle armature, devised by Siemens. It consists of a single coil of wire wound lengthwise upon an iron "shuttle", see Figures 3 and 4.

When this is revolved between the poles of a magnet a current

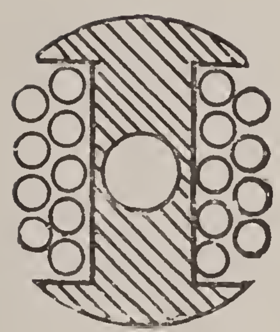


FIGURE 3.

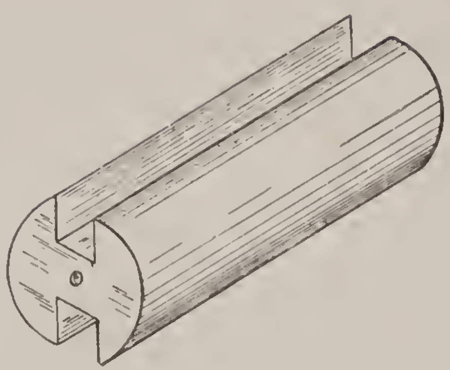


FIGURE 4.

is set up in the wire, the direction of which may be determined by the following "rule of thumb." Spread out the thumb and first two fingers of the right hand in such a way that each will be at right angles to the other. See Figure 5.

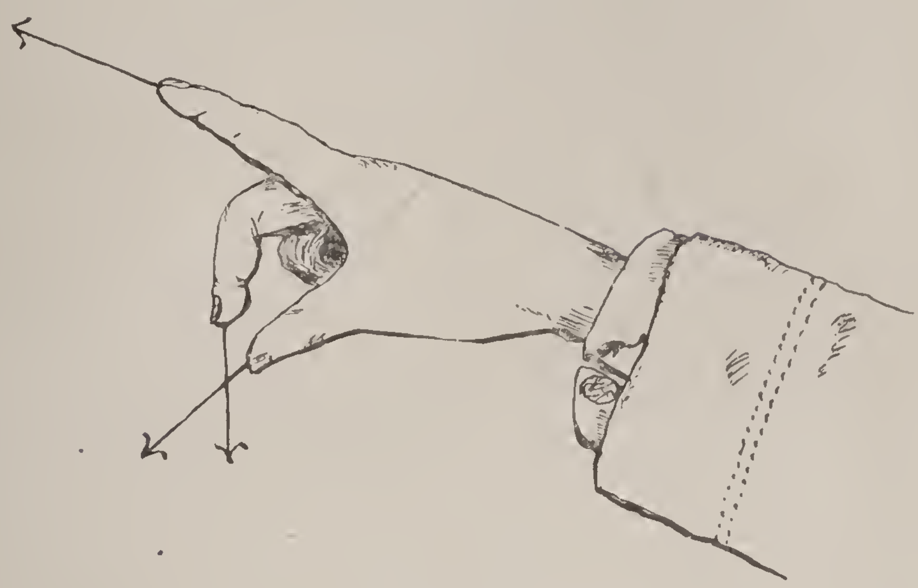


FIGURE 5.

Then if the thumb be pointed in the direction of motion of the wire, and the forefinger in the direction of the lines of force (that is from the north to the south pole of the magnet), the middle finger will be pointing in the direction of the induced current. It will be seen by applying the rule to the coil just spoken of, we find that the current in the wire will reverse at each half revolution, and that if we desire the cur-

rent in the external circuit to be in one direction, we must place what is known as a commutator at the point where the current is led from the armature. The commutator in this case will consist of two halves of a metallic cylinder attached to the armature shaft, but insulated from it and each other. The ends of the coil are fastened one to each half of the cylinder, and the brushes or collectors which lead off the current rub against them. See Figure 6.

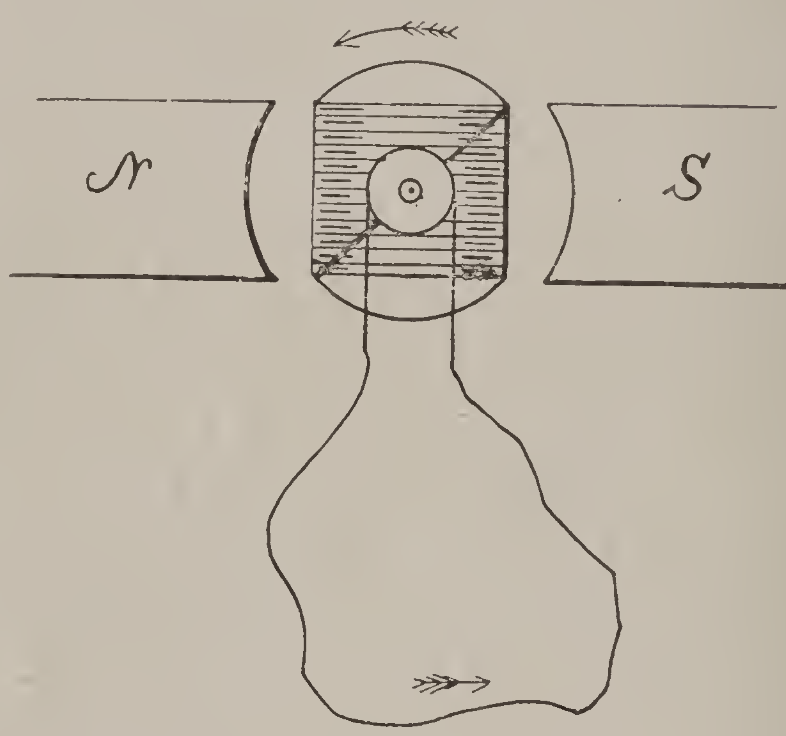


FIGURE 6.

When the armature is in the position as shown in Figure 6, the current in the external circuit will flow as indicated by the arrow, and when the armature makes half a revolution its current will be reversed, but at the same time its connection with the external circuit is reversed by the commutator, and the current still flows there in the same direction. When the armature has made a quarter revolution, or stands at right angles to its present position, the brushes will touch both segments of

the commutator, and the coil is short circuited, but at the same time it will be seen that the wires of the coil are not moving across the lines of force but parallel to them, and that they are therefore generating no electro-motive force, so that there is no harm done; that is, there would be none if the above statement were accurately true. Practically, if the coil has any breadth it cannot be moving parallel to the lines of force at every point, at the same instant, and a sufficient current may be generated during this period to cause a spark to form when the short circuit caused by the brushes passing from one segment of the commutator to the next, is broken. In well-designed machines, this can be avoided by attention to the shape of the pole pieces of the fields; that is, by so making them that few, if any, lines of force are cut by the coils when short circuited. The current given by the above arrangement, while it flows in but one direction, is, nevertheless an intermittent one, varying from its maximum when the coil is horizontal, to nothing when it is vertical and short circuited. If we wind another coil on the armature with its plane at right angles to the first, we shall evidently lessen this tendency, for when one coil is in its idle position, the other will be doing its best work, and *vice versa*, but there will still be a jog in the current strength, though to a much smaller degree.

Three coils would evidently be a step further in the right direction, and in fact, the greater number of coils we use, and a like number of commutator segments, the nearer we come to having a smooth current. The number is limited by the difficulty of construction, which increases with each additional commutator segment. In the usual construction of the closed coil armatures the end of one coil is connected to the beginning of its next neigh-

bor, and a wire is taken from this junction to a commutator bar and there must be as many commutator segments as coils. This arrangement is best shown on a Gramme ring, but the principle is the same for any style of armature. See Figure 7.

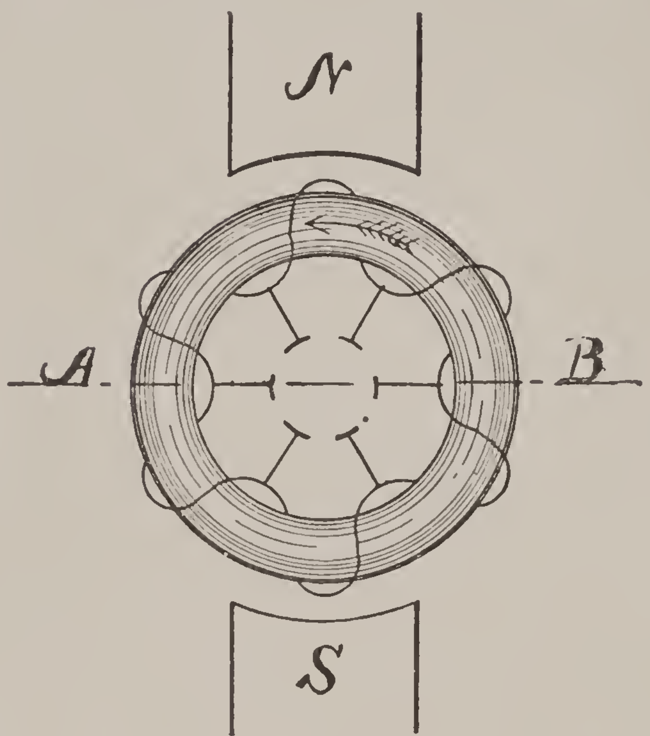


FIGURE 7.

In the sketch showing this arrangement it may be seen that the current in the armature is flowing in the opposite direction, in the halves made by the line A B. In each case it flows from B to A, and therefore if the brushes be placed on the line of A B, they will be in proper position to take the current. In an open coil armature, that is, one in which each coil is by itself, and has no connection with the others, the brushes must be on a line at right angles to A B, or so that they will take off the current when the coil is generating the highest electromotive force. The flow of electricity (that is, in steady currents) in a conductor is, by ohms law, directly proportional to the electromotive force, and inversely proportional to the resistance of the conductor. Sylvanus P. Thompson says

"For sudden currents, or currents whose strength is varying rapidly, this is no longer true. And it is one of the most important matters, though one too often overlooked in the construction of dynamo-electric machinery, that the 'resistance' of a coil of wire, or of a circuit, is by no means the only obstacle offered to the generation of a momentary current in that coil or circuit; but that, on the contrary, the 'self-induction' exercised by one part of the coil or circuit on another part or parts of the same, is a consideration, in many cases, quite as important as, and in some cases more important, than the resistance." The method of field winding will depend largely upon the form of the field core, and we will briefly discuss this before going further.

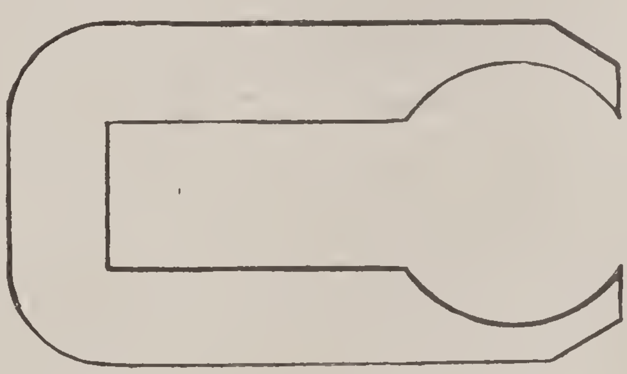


FIGURE 8.

Cast-iron cores will, in most cases, be cheapest to construct, but a wrought core is always the most effective electrically. A cast-iron core can be made almost any shape, but there is a limit to the number of shapes into which wrought-iron can be made, unless an expensive amount of forging is done. One wrought-iron form, which can be made without much trouble, is shown in Figure 8.

After bending into shape, the space for the armature can be bored out, and the winding slipped over spools. The fields of a dynamo must be connected up in such a way as to make

the pole pieces north and south magnetic poles. To know if the pole is north or south, look at the winding at the end from which it projects, and if the current goes in the direction of the hands of a watch, the pole is south, and if in the contrary direction, it is north. See Figure 9.

FIGURE 9.

If more than two poles are used, they must alternate north and south. In making the armature and field connection you must be careful to get the machine connected for the way in which it is to run. A dynamo or motor will not run in either direction indifferently; if you run the dynamo in the wrong direction it will not generate a current.

*"The name of 'field-magnet' is properly given to that part which, whether stationary or revolving, maintains its magnetism steady during the revolution; and the name armature is properly given to that part, whether revolving or fixed, which has its magnetism changed in a regularly repeated fashion, when the machine is in motion."

In this book, however, we shall treat only of dynamos in which the armatures revolve, the field magnet remaining stationary.

Electro-magnets are practically magnetic only when a current of electricity is passing through their coils. There, however, remains a feeble residual magnetism in the pole pieces of

* S. P. Thompson's "Dynamo-Electric Machinery."

dynamos, which, when excited by rotating the armature at a high rate of speed, within the magnetic field, will induce a small current in the coils, which rapidly increases, and on being transmitted through the coils of the electro-magnets, augments their magnetism and produces in them still stronger currents.

CHAPTER III.

METHODS OF FIELD-MAGNET WINDING.

THERE are two types of dynamos — the continuous current and the alternating current. In the continuous current machine the current generated is made to flow in one direction by the use of a commutator, from which the current is collected by brushes and carried to the external circuit. In the alternating current machine the current generated flows at rapid intervals, first in one and then in the opposite direction. This dynamo, having no commutator, a collector of two metal rings is necessary, on which the brushes rest. The field-magnet of this machine must have a continuous current to excite it, and this current is usually supplied by another small continuous current machine, which is called the exciter. There are five simple methods of exciting the magnetism that is to be utilized in the magnetic field.

In the "magneto machine" (found only in small types today) no attempt is made to make the machine excite its own magnetism, this being provided for by the use of a permanent magnet of steel. It has the disadvantage of the permanent magnets becoming gradually diminished in strength by every mechanical shock or vibration to which the machine is subjected. A diagram of this machine is shown in Figure 10.

It is used principally for magneto call bells and for medical and experimental purposes.

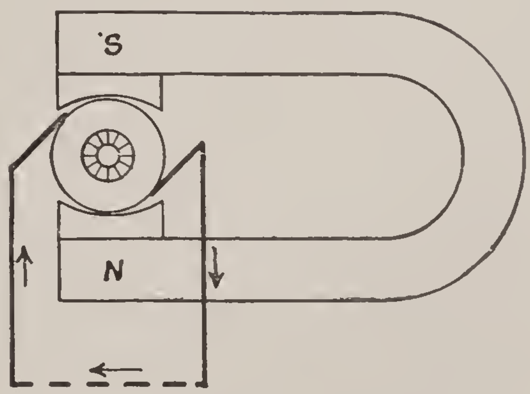


FIGURE 10.

The separately excited dynamo (a diagram of which is shown in Figure 11) possesses the property that, saving for

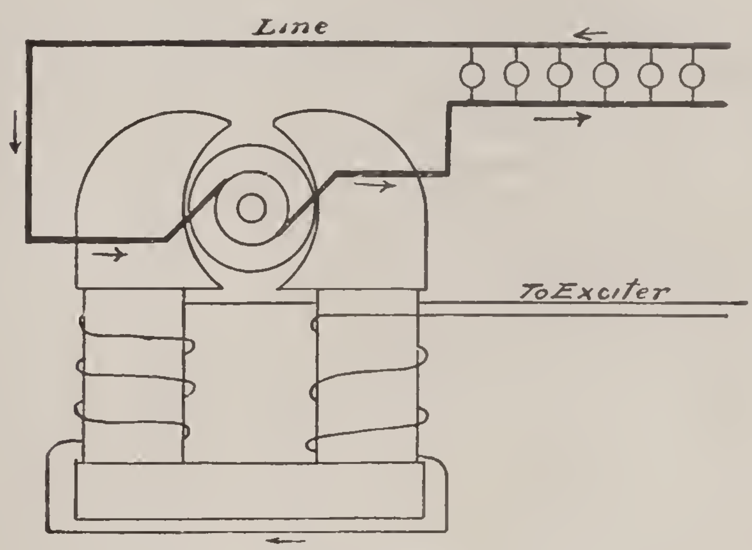


FIGURE 11.

reactions due to the armature current, the magnetism in its field, and the electro-motive force of the machine, is independent of changes of resistance going on in the working circuit. This machine may be governed by altering the speed, or by altering the amount of magnetism that passes across the armature. There are two other ways of weakening the effective magnetism, both by reducing the exciting current: (1) by introducing

a resistance into the exciting circuit; (2) by altering the number of turns of wire around the field magnets.

There are three kinds of windings for self-exciting dynamos, namely: the series, the shunt, and the compound.

The series dynamo has but one circuit. The current generated is passed through the field-magnet coils, which are connected in series with the armature and external circuit. See Figure 12

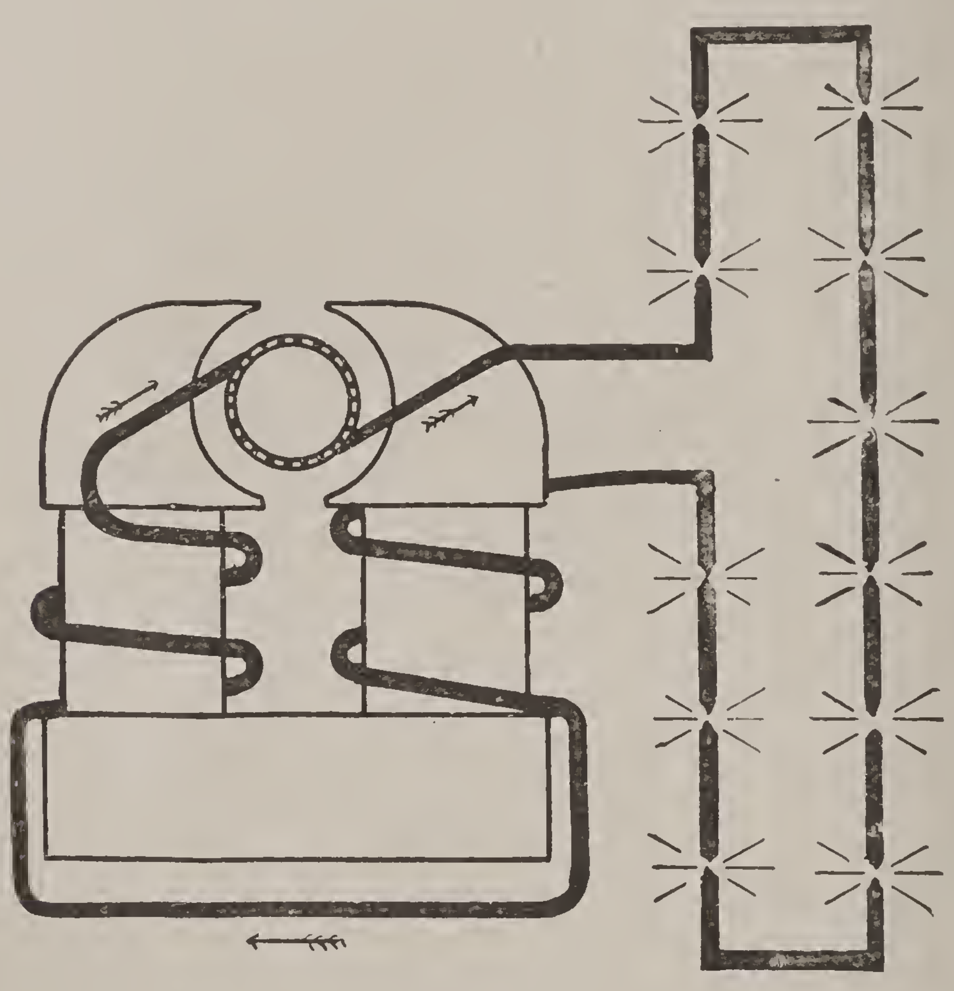


FIGURE 12.

This machine will not generate a current until a certain speed has been obtained, or unless the resistance of the circuit is below a certain limit; the machine refusing to magnetize its own magnets when there is too much resistance or too little speed. This type of machine is liable to reverse its polarity, a

serious fault, which unfits it for use in electroplating and for charging storage batteries. These machines are generally employed for arc lighting.

In the shunt wound dynamo the field-magnets are wound with many turns of fine wire, to receive only a small portion of the whole current generated in the armature. These coils are connected to the brushes of the machine and constitute a by-pass circuit, or what is called a shunt. See Figure 13.

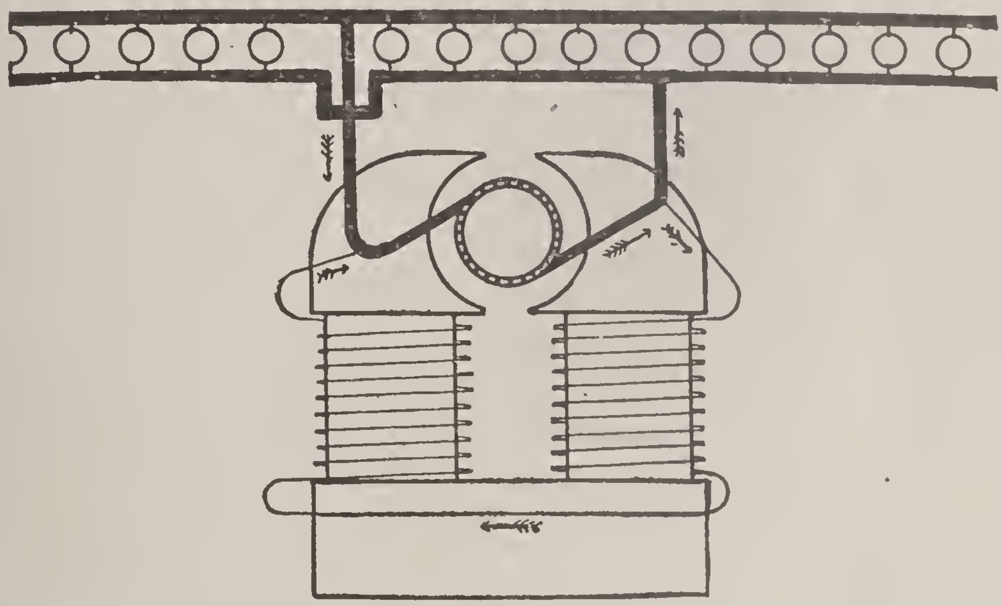


FIGURE 13.

In the compound wound dynamo we have a combination of the series and shunt winding. The field-magnets are wound with two sizes of wire — coarse wire, which is in series with the armature and the external circuit, and a finer wire, which is in shunt with the brushes. This machine is nearly self-regulating, and is used largely for incandescent lighting. If the shunt coils be comparatively few, and of high resistance, thereby causing their magnetizing power to be small, the machine will give approximately a uniform pressure of a few volts; whereas, if the shunt be relatively a powerful magnetizer, as compared with the few coils of the main circuit, it will be capable of

giving a constant pressure of a large number of volts. Each coil corresponds to a certain rate of speed, depending on the arrangements of the machine. A diagram of the compound wound dynamo is given in Figure 14.

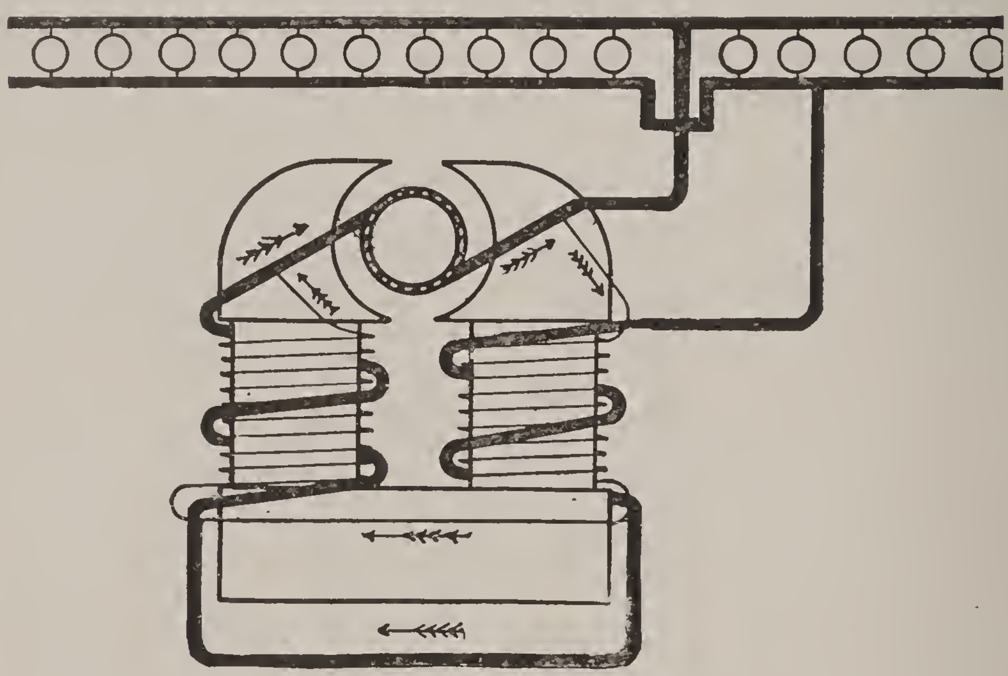


FIGURE 14.

CHAPTER IV.

FORMS OF FIELD MAGNETS.

Most dynamos have but one field magnet, but special forms are made in which several magnetic "fields" or regions are available. Electro-magnets, more powerful and compact than permanent forms, are almost exclusively adopted. The ends of "field magnets" are usually made to embrace a large portion of the revolving armature. Where a permanent magnet is used as in a magneto-machine the magnet can be with extensions, as shown in Figure 15. These ends are called pole-

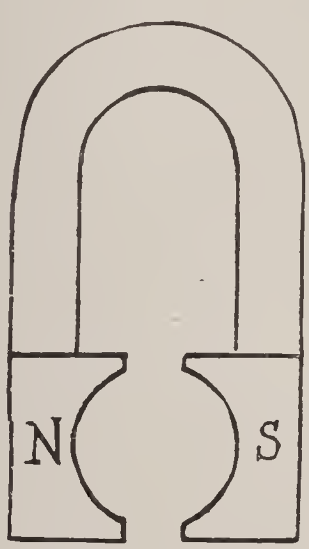


FIGURE 15.

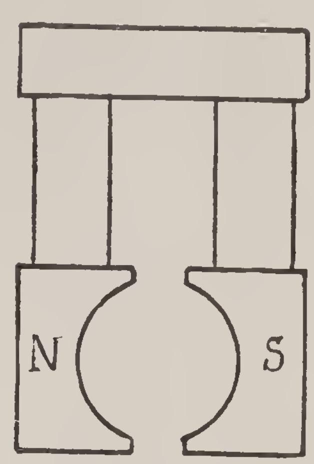


FIGURE 16.

pieces as they become the poles of the magnet. Five separate pieces are usually joined together to form an electro-magnet for the type of dynamo shown in Figure 16. The two pole-pieces are of cast iron, the two cylindrical "cores" of wrought, as is also the "magnet yoke" which connects the cores together.

The surfaces where these separate pieces touch are made very smooth and flat, in order that the magnetic circuit may be as if in only one piece of metal. This form is convenient for handling and allows easy application of the coils of wire. It is not best to wind this directly on the iron, but to have it wound on detachable spools. Simple brass rings connected with a sheet-iron or tin cylinder is strong enough, and the spools fit loosely over the cores. Such arrangements as shown in Figures 15 and 16 furnish magnets with "salient" poles, that is, virtual poles at the very ends of the cores. If another set of cores be added to the other side of the pole-pieces a magnetic field of twice the strength of the above arrangement can be obtained. See Figure 17.

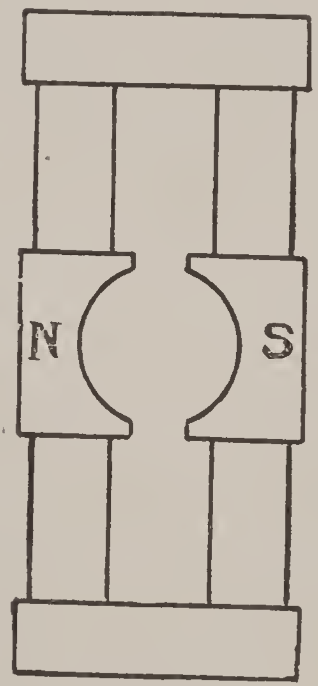


FIGURE 17.

In this form the poles are "consequent," for the magnetism is available in pole-pieces which are interruptions in the otherwise continuous iron. Figures 18 and 19 show a type of field magnet where only one core is used, consequently only one spool of wire is necessary. Figure 18 shows one position

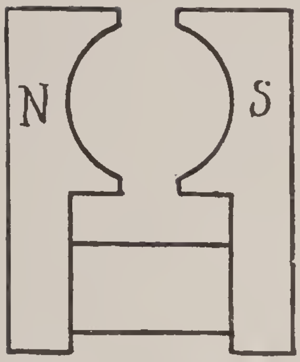


FIGURE 18.

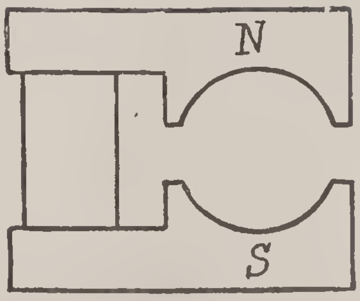


FIGURE 19.

and Figure 19 the same with its core perpendicular. By doubling this form we have Figure 20. By lengthening the

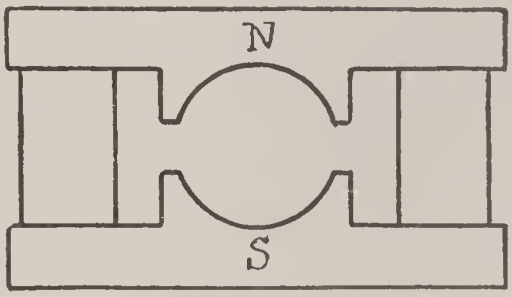


FIGURE 20.

pole-pieces into cores this form becomes merged into Figures 21 and 22.

Just which four of these field-magnets is best to use depends

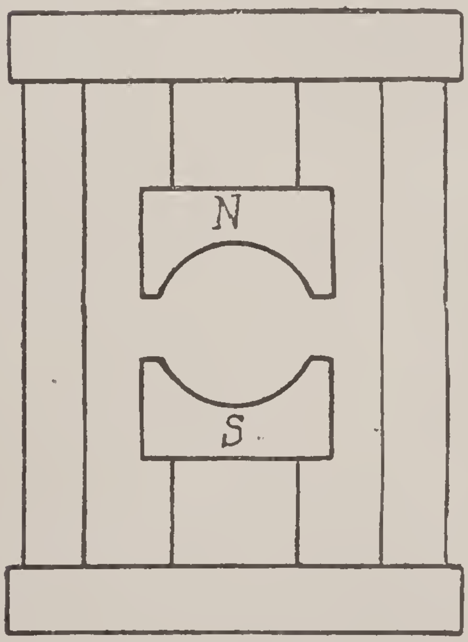


FIGURE 21.

on the purpose for which the dynamo or motor is designed. Sometimes, for the same purpose, different forms work equally well. Usually dynamos for continuous currents have but two poles as shown in these figures. By increasing the number

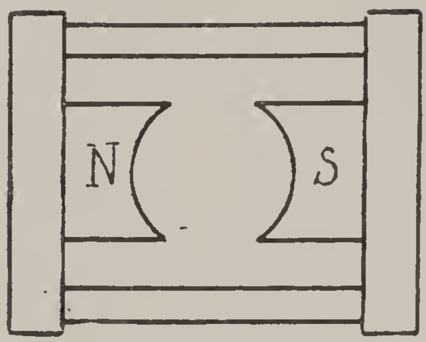


FIGURE 22.

of poles, as shown in these figures, the armature will receive the desired number of inductions at a slower speed of rotation. A four pole field-magnet is shown in Figure 23. The cores are also used as pole-pieces. Figure 24 shows a six pole field-magnet. This form can be used for continuous current but it is better adapted for alternating. An alternating current

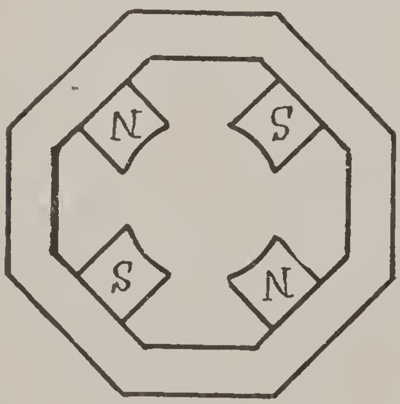


FIGURE 23.

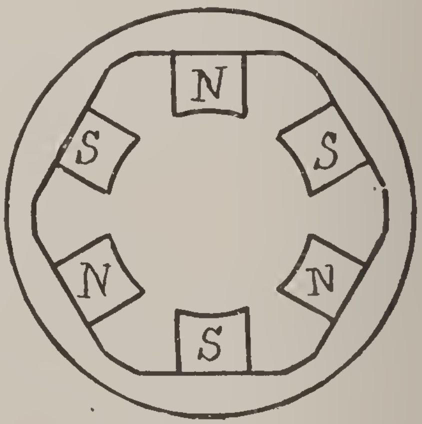


FIGURE 24.

dynamo should have a large number of poles in order to give a rapid alternation. Two hundred and fifty reversals per second is commonly attained. It is not unusual for an alternating machine to have from sixteen to twenty poles. For future machines the promise is for even a larger number. The

more poles a machine has the slower the speed can be, and the tendency now is toward slow running machines. For arc dynamos the amount of iron in the magnets should be comparatively small, but a large amount of copper wire needs to be used on the spools. Arc dynamos are series-wound, so that the entire current from the armature circulates around the field-cores. The field is in "series" with the rest of the circuit. When this winding is used the field-magnet experiences every fluctuation of the current which lights the lamps, which varies the magnetism and is utilized in adjusting the regulator. An arc dynamo preserves a current of uniform strength, but the potential or voltage varies according to the number of lamps supplied in the circuit.

A dynamo for incandescent lighting or for supplying power to motors should have a constant voltage, but the strength or quantity of current should be dependent on the demand. For such a machine there should be a very massive field-magnet. The winding should be in "shunt," that is, the field spools should be in a circuit independent of the working circuit. This subtracts a certain amount from the useful output of the machine, but if the wire is fine and of considerable length, the resistance being sufficient to allow only about one-hundredth part of the whole current to pass around the field-magnets, the magnetism is thus kept nearly constant, and the potential is uniform.

Absolute constant potential can be obtained by "compound" winding. To get just the right amount of wire on the field-magnet is no easy task, without elaborate data. Manufacturers usually wind a temporary coil on each spool for experimental purposes. These spools are placed over the "cores." The

armature is then rotated at its calculated speed, and current from another source is sent through the temporary field-wire. From measurements of the number of turns of wire, and the current necessary to bring the machine to its proper output, the final winding may be calculated. It is desirable to use as large wire as possible, in order that the heating effects be low. About 1000 amperes to the square inch of cross-section of wire is a safe allowance. For arc dynamos the wire needs to carry about 10 amperes. For a "shunt" wound dynamo from one to three amperes. In a compound wound dynamo the shunt is the same as in the previous case, but the series coils needs to be sufficiently large to carry, in some cases, several hundred amperes.

A dynamo should be designed in such a manner as to economize material. The iron of the magnet should also be compelled to form the frame for the machine, and give places for the armature bearings. No part of the magnetic circuit should have less cross section of iron than the "cores." This rule has not always been observed, hence a large amount of external magnetism, or leakage, has been the result. That is to say, that some of the magnetic lines which are excited in the field-magnet fail to pass through the armature, and leak out sideways, thereby constituting a "stray field" around the dynamo. In some machines more than one-half of the magnetic lines are wasted in this way. The nature of this leakage may be easily comprehended by remembering that air is a magnetic conductor, though not as good a conductor as iron. A perfect dynamo will exhibit no outside magnetism, all being utilized within for useful work.

The size of field-magnets is dependent on the armature.

The capacity of a dynamo lies in its armature, and for that the first calculation is made. Afterwards suitable field-magnets can be designed. An early error in dynamos was to use very long "cores" At present they are very short and the magnetic yoke massive. The diameter of the "cores" for most purposes should be two-thirds or four-fifths of the diameter of the armature, and their length about equal to the diameter of the armature.

An important consideration in the design of magnets is to keep in mind accessibility to the armature. It is not advisable to remove or replace an armature endwise, but the field-magnets, in part or whole, should be easily removed, and leave the armature open for inspection or removal. The reader will remember that in selecting his form of field-magnet the best results will be obtained from those having the most compact form, the greatest cross section, the softest iron, and the fewest joints. A larger variety of forms of field-magnets might be shown in this chapter, but the author thinks he has shown enough to enable the reader to form a fair idea of the ordinary types. One thing must not be forgotten, that the air space between the pole-pieces and the armature core should be made as large as possible in area and as thin as practicable.

The pole-piece projections should not be too near to each other, nor should they be too near other iron parts, on account of leakage. They should also be rounded off on their outer edges, for these projections are often the most intense parts of the field-magnets, and the waste of magnetism by leakage from them is, in some cases, enormous.

In conclusion.—No rule can be laid down for selecting the best form of field-magnets. The best for one purpose is not the best for all. Some designs are best made of cast-iron,

others of wrought iron, and then, again, best results may be obtained from the composite form, having cast-iron polar masses and wrought iron bobbins. The large machines will need a number of poles, while in the small machines a simple circuit will be the best.

CHAPTER V.

ARMATURES.

Every dynamo-electric machine has an "armature." Its purpose is to convey the magnetism from one pole-piece to the other. This name is borrowed from the phraseology adopted in the days when horseshoe permanent magnets were invented. The soft piece of iron called the "keeper," across the poles of a permanent horseshoe magnet is familiar to everybody. This is technically called an armature. Armatures of dynamos are generally cylindrical and have imbedded in them or laid upon their surface insulated copper wires, for conducting the currents of electricity which are generated when the armature revolves. The iron centre upon which the wire is wound is called the "core." The whole is generally mounted upon a suitable shaft. One of the earliest armatures is the Siemens, or shuttle form. It consists of a cylinder of wrought or annealed cast-iron, which is grooved on both sides and the recesses filled with wire wound back and forth. To each end is screwed a brass head, into which short shafts are fitted. These shafts, besides supporting the armature in position, carry the driving pulley and the commutator. The commutator has but two parts, to which (after being carried through a hole in the shaft) the two ends of the coil are attached. This form of an armature is very

energetic and is well adapted to small dynamos for intermittent work. When run continuously this form heats, on account of the large mass of iron in the "core."

The two forms of armature most commonly met with in practice are the Gramme ring and drum, or variations of them. The Gramme ring armature consists of a ring or hollow cylinder of iron, upon which the wire is wound. Instead of going completely around the outside of the armature, each turn of wire goes through the opening in the middle and thence back to the outer surface again. On an armature of this description each coil is wound by itself and is not overlapped by any of the others, consequently, if repairs are necessary at any time it is easy to get at the particular coil where the fault exists without disturbing any of the other coils, and this is often an important point, especially where the armature is wound with a large number of turns of fine wire. The coils, being each one open to the air, get better ventilation, thereby reducing the heat generated in the wire and core of the armature. On the other hand, the wire which passes through the middle of the armature is "dead," so far as to exciting an electro-motive force, and it does not help, but adds a wasteful resistance.

The ring armature is more difficult to wind than the drum armature, as the wire must be passed through the middle for each turn. The cross section of the ring armature core is also necessarily smaller than a drum armature of the same dimensions, therefore its magnetic resistance is greater. In a general way we may say that the ring armature is better adapted for machines designed to give a constant current and a high potential, while a drum armature is the proper kind to use for constant potentials and large currents. The core of a ring

armature can be made in several ways. It should *never* be a solid piece, on account of the eddy currents which would be induced in it and cause it to heat. It might be made of a flat ribbon of sheet iron, wound up to form a cylinder, but this will have, to a smaller degree, the same objection as the solid core. It is frequently made of iron wire wound on a "former" of wood, and shellacked and bound with tape to make it keep its shape. This method has many advantages; it is cheaply and easily done, and gives good results, and unless one has special facilities for doing the work, is probably the best. A core of this sort, however, is slightly inferior, considered as a magnetic conductor, to one made of discs or flat rings of sheet iron. Magnetism always shows a preference for running along

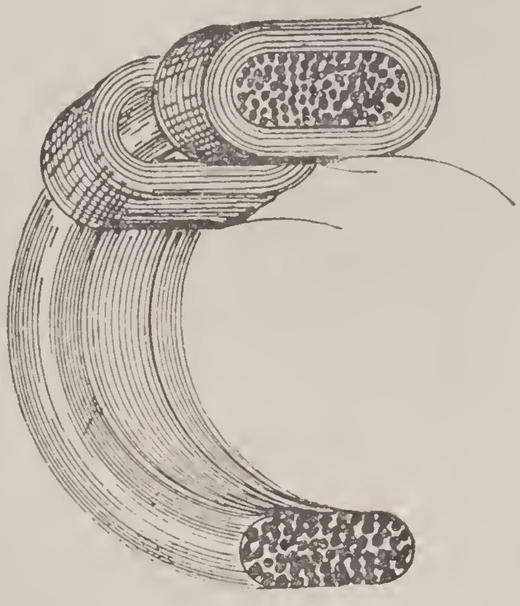


FIGURE 25.

the grain of the iron, and it will have more difficulty in getting out of the centre of a core made of wire, (where it will have to go at right angles to the grain and besides, have numerous air gaps to leap across), than it would to get out of a similar core made up of discs. A ring armature with a core made of iron wire is shown in Figure 25.

If a core made of rings cut from sheet iron is used, some means must be devised to hold them together. This may be done by a bolt or screw through them from end to end, or they may be held by the "spider" by which they are attached to the armature shaft, as shown in Figure 26

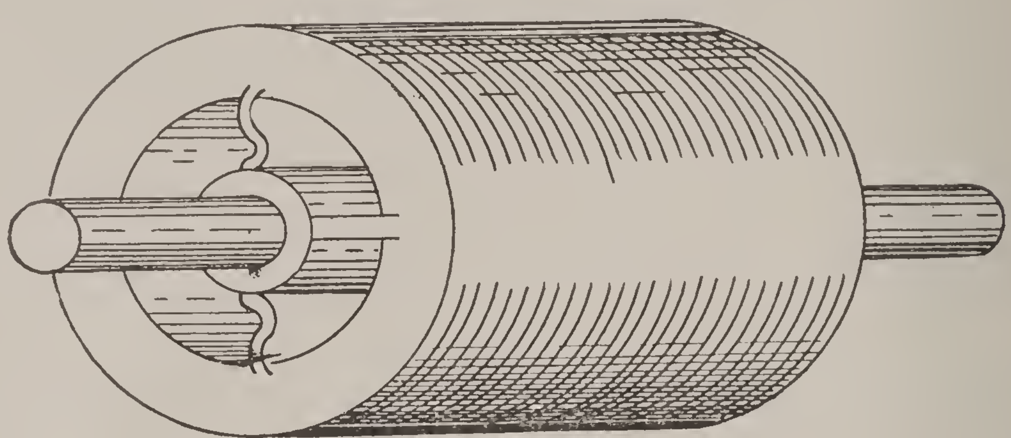


FIGURE 26.

There is no need of paper or any other insulation between the discs; the black oxide of iron on the surface is sufficient. The danger of heating is not so much from the small currents in the discs jumping across from one to another, as from the lines of magnetic force going through the armature slantingly. The length of the armature core should equal the width of the pole pieces, in order that the lines of force may go straight from one pole to the other. The wires on the armature must always be very carefully insulated from the core. On small machines this may be done by covering the armature core with two or three layers of wrapping paper, sticking it on with shellac. On large machines a layer of canvas should be placed between the papers to lessen the liability of breaking through on corners and sharp edges. For if this insulation should rub through or be crushed at one point, the whole electro-motive force of the machine will act at another point, thereby bursting

through the insulation and causing the current to "jump" through to the core and thus burn out the armature.

In regard to the necessity for some means of holding the armature coils in place, there is a diversity of opinion. Some manufacturers wind coils on a smooth core and trust to friction and good luck to hold them where they are placed, while others use various methods to hold them there. The strain on these coils is caused by the resistance against which the armature must be turned, and the effect is very much the same as if a brake was applied to the surface of the armature to prevent its rotation. One method employed to prevent the coils from slipping is to bore holes in the external surface of the armature core

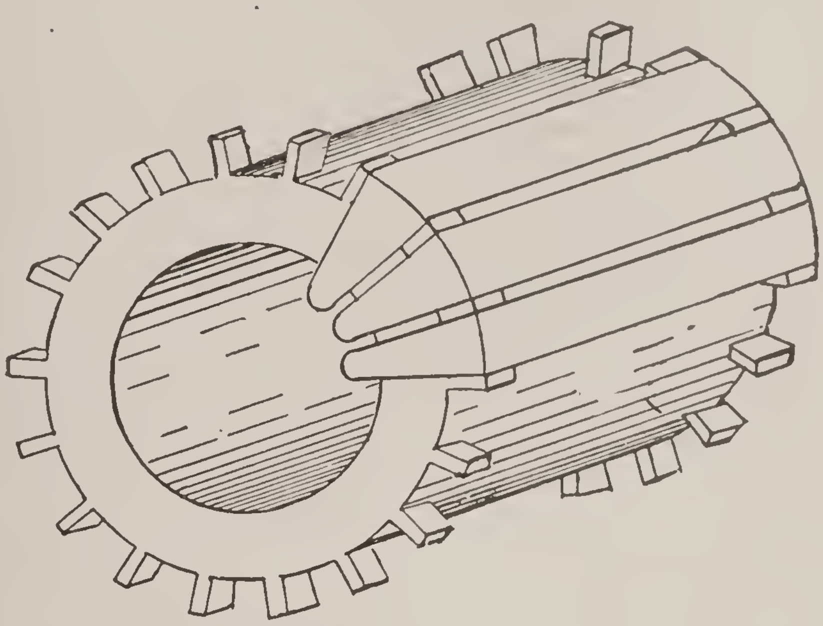


FIGURE 27.

close to the ends between the coils, and drive pegs, either of wood or iron, into them, as shown in Figure 27. If iron pegs are used they must be insulated.

Another, but more expensive way, is to make the discs which form the core of the armature like a toothed wheel. See Figure 28.

When these are put together to form the core the projections will make ribs, running the length of the armature core, between which are channels in which the wire may be wound. This not only gives a solid construction, but also has the advantage of reducing the magnetic resistance of the air space.

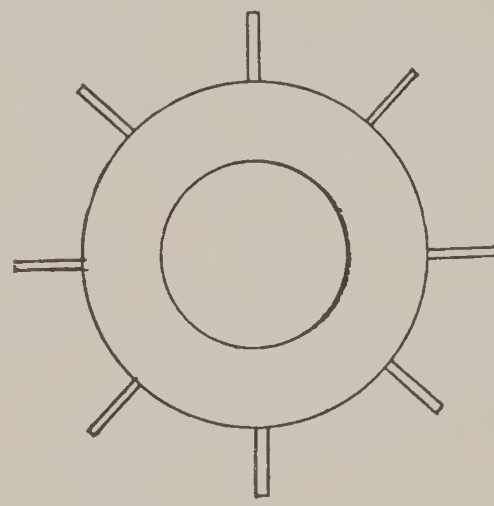


FIGURE 28.

A good proportion for cylinder armatures is for the diameter to be two-thirds its length. In the ring form the diameter should be about twice its length.

A safe calculation in winding drum armatures is to reckon one volt for every two feet of active wire. Very small machines are not so efficient as large ones. A "core" seven inches outside diameter, five inches inside, and four inches long, wound in forty-eight sections with No. 15 wire will furnish a current of about 80 volts and 15 amperes. The wire must be two layers deep, and the armature driven at about 2200 revolutions per minute. A field-magnet of style shown in Figures 15 or 22 would be suitable for the armature described above. By using wire one-half the size and making twice as many turns, a four-pole field-magnet can be used. Twelve pounds of No. 12 wire will be sufficient for the field-spools. If it is necessary

to piece wires in the armature coils, the joints should always be soldered, being careful not to make a lump in the winding, which will be unsightly or in danger of touching the pole-pieces.

The last operation is to put on the binding wire. This is to prevent the winding from flying out when the armature is run at a high speed. The number of bands needed will depend upon the length of the armature. A small armature may need only one, while a large one will need three or more. These bands should be about one-fourth or one-half of an inch wide, wound on tightly and soldered at intervals their whole width.

The connections to the commutator can be made by either screws or solder, but perhaps best by both. In some cases it is considered better to solder the wires to flat strips, which may be bent around the wires to make a better connection, and then screw and solder these strips to the commutator bars, their shape allowing them to make a better contact than the round wires.

After an armature is finished it must be properly balanced, otherwise it will be liable to vibrate when running at a high speed, which will be augmented by the consequent unbalanced pull of a strong field on the armature, due to the core vibrating so as to come nearer to one pole-piece than the other. If this vibration becomes too violent it may cause the armature to abrade its surface on the pole-pieces, thereby cutting its bands, often resulting in short circuiting and total destruction of the armature. To balance an armature, place the two ends of the shaft upon two parallel metal rails (or knife edges). The armature will usually come to rest in some particular position, which shows that the upper side needs more weight. If badly out of balance some pieces of lead can be wedged

under the binding band. If only a little out of balance add a little solder to the binding wire on the light side, until the armature will stay in any position that you may place it.

Properly made, there is no electrical difference between the drum and ring forms for armatures. Where a narrow machine and high speed is desirable the drum form is the best; while for a short shaft and slow speed the "ring" offers valuable advantages. For further information about "armatures" the reader is referred to the author's book, "Armature and Field-Magnet Winding." We have devoted all the space in this book to this subject that can be spared, and in the following chapters explicit directions and full working drawings will be given to enable the reader to wind the armature of each machine, therein described, to obtain the output for which it is designed.

CHAPTER VI.

HOW TO MAKE A TOY ELECTRIC MOTOR.

A COMMON weakness of toy motors of any kind is their brevity of life. Miniature steam engines, being made of soft metal, soon wear out, and electric motors have some delicacy of construction that is easily deranged.

In this chapter an attempt is made to describe a motor of such size and substantial design as not to be easily injured, and of such simplicity that a boy may quickly build it. The mechanism is self contained. Figure 29 shows the assembled machine in plan and elevations.

The field-magnet is an iron casting, although a piece of wrought iron could be bent to the necessary shape. Figure 30 represents the detail of this part. The central portion, called the core, is round where the winding is to be located, but divided into two spaces by a collet that serves to hold one end of the armature shaft. At each extremity of the winding space rises a rectangular pole-piece, the upper ends of which are tapped "8-32" for screws that hold the upper bearing for the shaft in place. This bearing consists of a flat strip of sheet brass one-eighth inch thick and one-half inch wide, as shown in Figure 31. The end holes are drilled large to allow a little adjustment. Figure 32 shows the revolving parts, consisting of a cross-shaped iron casting for the armature, a piece of square brass for the

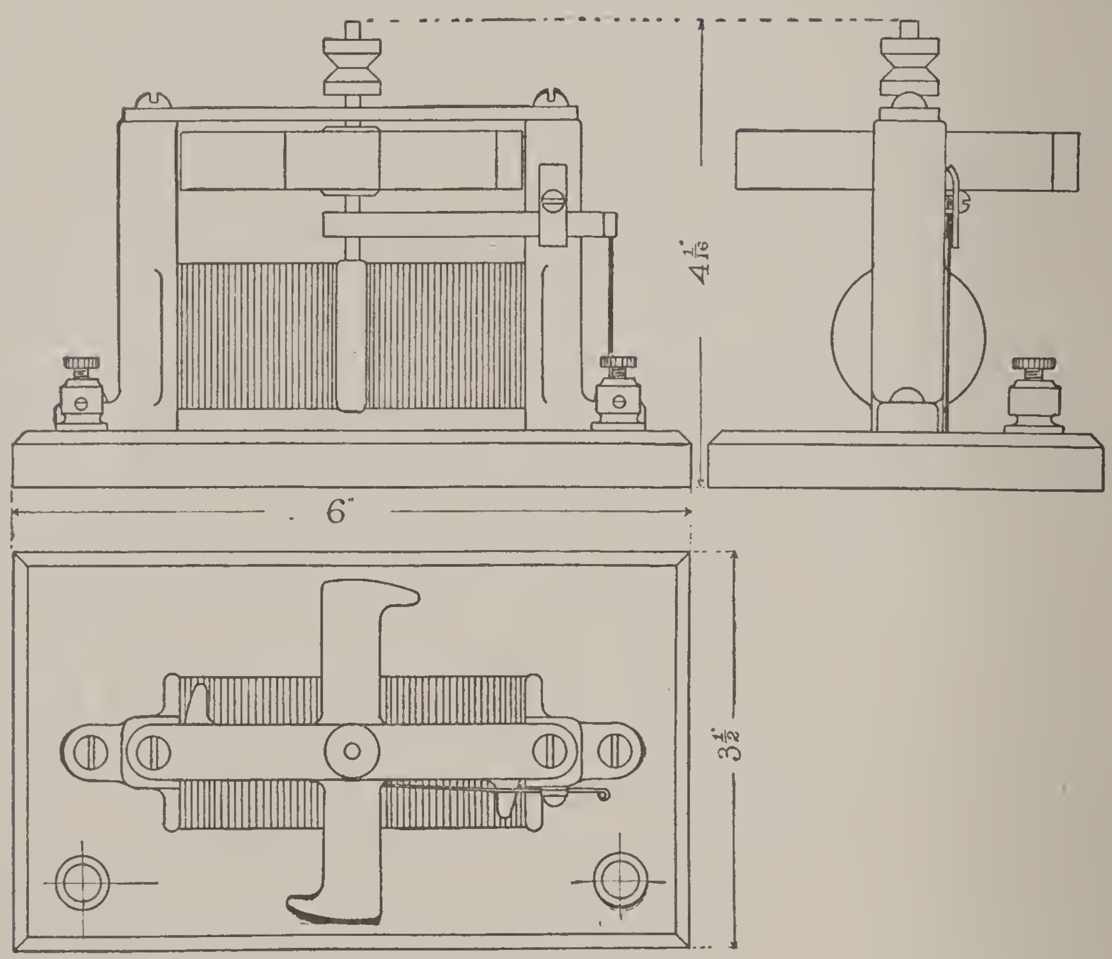


FIGURE 29.

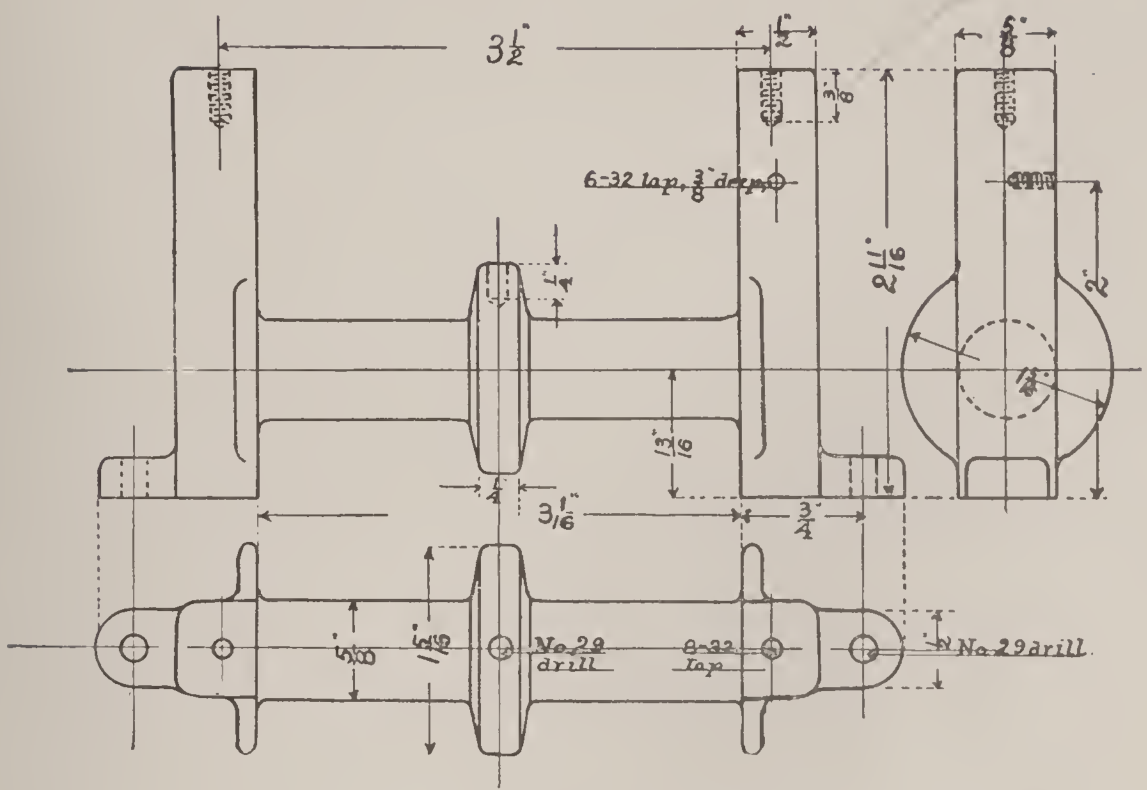


FIGURE 30.

commutator, and a piece of one-eighth inch steel or iron wire for the shaft. A wire nail will answer for the latter. Horns on the ends of the armature increase the scope of the field. The armature and commutator are to be tightly driven on the shaft; it will be noticed that the sides of the two are not exactly parallel; the commutator is given a little "lead."

In the assembled drawing the location of the single brush is shown. It consists of a piece of thin and springy sheet copper or brass. It should be not over one-hundredth of an inch thick, one-fourth of an inch wide, and three and one-half inches long, with the exterior end soldered to a wire that leads to one binding post. A piece of thick paper for insulation is wrapped one turn around the brush where it crosses the cast-iron pole-piece. A clamp of brass or iron one-sixteenth of an inch thick, five-sixteenths of an inch wide, and three-fourths of an inch long, with the aid of a three-eighths 6-32 screw, holds the brush in position.

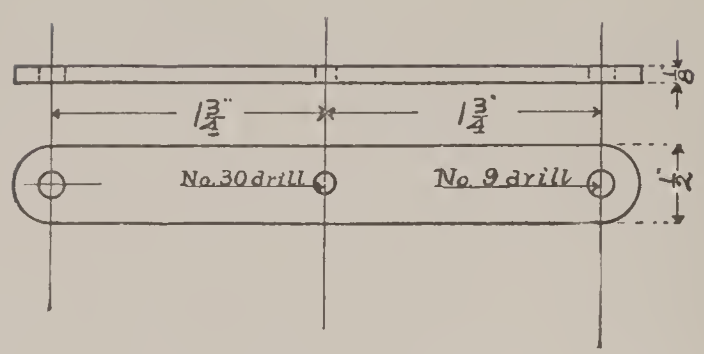


FIGURE 31.

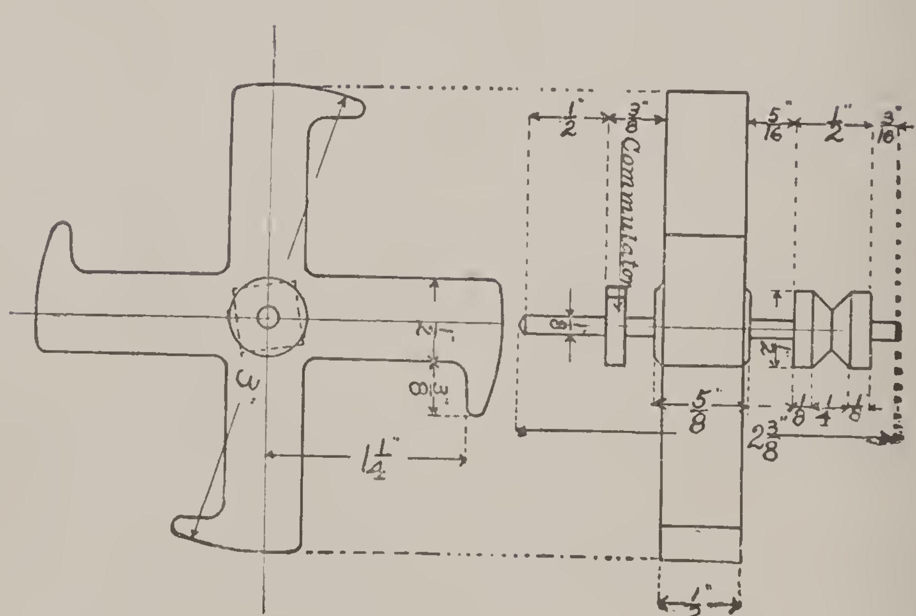


FIGURE 32.

After the mechanical part of the work has been completed, the builder can easily add the electrical equipments. The winding can be quickly done in a lathe. No. 18 wire, either single or double covered, is suitable. Provide about one-half pound. Strip the insulation off for a distance of four or five inches and begin winding one of the spaces. When it is filled, continue into the other until that also is filled, then connect to the second binding-post; it will be well to wrap a turn or two of thin paper around the iron in the second coil, as there should be no connection with the iron except at the very beginning. The electrical circuit will be finally as follows:—Entering at the binding post just mentioned, the current will pass around the field-coils, magnetizing the iron, then enter the iron through the bared portion, to the armature, shaft, the commutator, brush, and by the wire to the other binding-post to the battery. The brush and commutator must be so adjusted that when the armature is in the position shown in Figure 29 the contact has just been broken. In starting the motor, a little push must be given the armature to get it off the "dead center." When it has turned a little way, one corner of the commutator will touch the brush, make a contact and magnetize the field. T e armature prongs that are approaching the poles will be vigorously thrust around; but at the instant the two pieces of iron are nearest together the commutator will have broken its connection and the field-magnetism vanished; momentum will carry the armature along until a second attraction has taken place. A speed of a thousand revolutions per minute can be easily attained by using a bichromate battery for a source of current. If sal-ammoniac or gravity cells are used, No. 24 wire will be more suitable than No. 18 for the winding.

On the upper end of the shaft a simple wooden pulley can be driven. This motor may be used to run small toys, fans, etc., or with a little ingenuity can be fitted to a small toy boat or electric car, but no appreciable amount of power can be derived. The only object is to make a device that will "go," and to illustrate in a practical way the principle of the electric motor.

CHAPTER VII.

HOW TO MAKE A SMALL DYNAMO.

THE dynamo and motor are theoretically identical, but in practice a slight difference is made in the design, especially of small machines.

This difference is mainly due to the necessity of having the magnetic circuit or path for the lines of magnetic force as perfect as possible in a dynamo, since it must itself supply the energy to excite the fields, and the strength of the fields regulates to a great extent the amount of energy the dynamo is capable of delivering. With the motor, this is different, for while it is necessary that the magnetic circuit be good, if a high efficiency is desired it is by no means necessary to the running of the motor since the energy to excite the fields is taken from an outside source, which, it is supposed, is capable of meeting all the demands which will ordinarily be made upon it.

It follows, therefore, that in order to have a dynamo capable of doing much, we must have perfect fitting joints between the iron parts of the fields and as little clearance as possible between armature and pole-pieces, and all this means good workmanship with good tools. We would, therefore, advise the amateur who does not possess these latter essentials to have the lathe work and planing done in some machine shop, as there is

not much of it to do, and the dynamo will work in a much more satisfactory manner than if the machine work is botched.

The shaft of our armature should be made of machine steel, one-half inch in diameter and nine and one-half inches long. The core of the armature is made of disks of sheet iron three inches in diameter and punched out at the centre just large enough to fit tightly on the shaft. If these disks are made of ordinary sheet iron the black oxide on the surface is enough to insulate them from each other. They can, however, be made of tin plate, in which case it will be necessary to place pieces of thin tissue paper between them. See Figure 33.

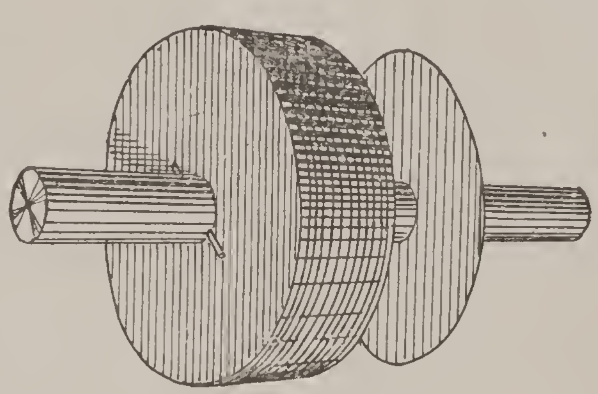


FIGURE 33.

Drill a one-sixteenth inch hole through the shaft, three and one-eighth inches from one end, and another three inches from this hole. Place a piece of one-sixteenth inch wire, one inch long, through one of the holes, and then put the disks upon the shaft, driving them tight against the wire, and when you have put on enough to make a compact cylinder three inches long, drive a piece of wire through the other hole to keep the disks in place. The core must now be insulated by covering it smoothly with two thicknesses of heavy brown paper, stuck on with shellac. The armature shaft, also, should be treated this way for an inch and a quarter from each end of the core. Be

careful to cover up every part of the core, as it will be the source of much annoyance if a contact develops between it and the wire.

Divide the circumference of each end of the core into ten equal parts, being careful to have the divisions at one end exactly opposite to those at the other. At each division mark saw a slot one-half inch deep across the corner. Into each of these slots drive a piece of stiff card-board or ebonite, as shown, leaving it to project about a quarter of an inch, and trimming it off even with the wire after the armature is wound, as in Figure 34.

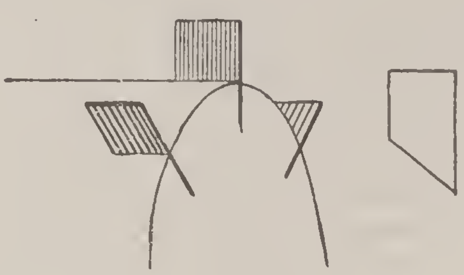


FIGURE 34.

We are now ready for winding, and for this purpose will need about two and one-half or three pounds of No. 18 double cotton covered copper wire. The winding we shall adopt is called the Siemens winding.

Begin at the end where the shaft is shortest and wind on the wire lengthwise on the core. The wire must be wound smoothly and tightly, but must be bent aside at the ends to allow for the displacement of the shaft. Be careful not to injure the insulation on the wire. Each coïl, if packed tightly, should have seventeen or eighteen turns. See Figure 35.

As soon as one coil is completed do not cut the wire but simply leave a loop two or three inches long and begin winding the next coil in the same direction. Begin the winding of each

coil on the right-hand side of the division and wind to the left, and begin the next coil where you leave off on the last. Give the loop a twist close to the core to prevent the first few turns of the wire on the new coil from getting loose. Before begin-

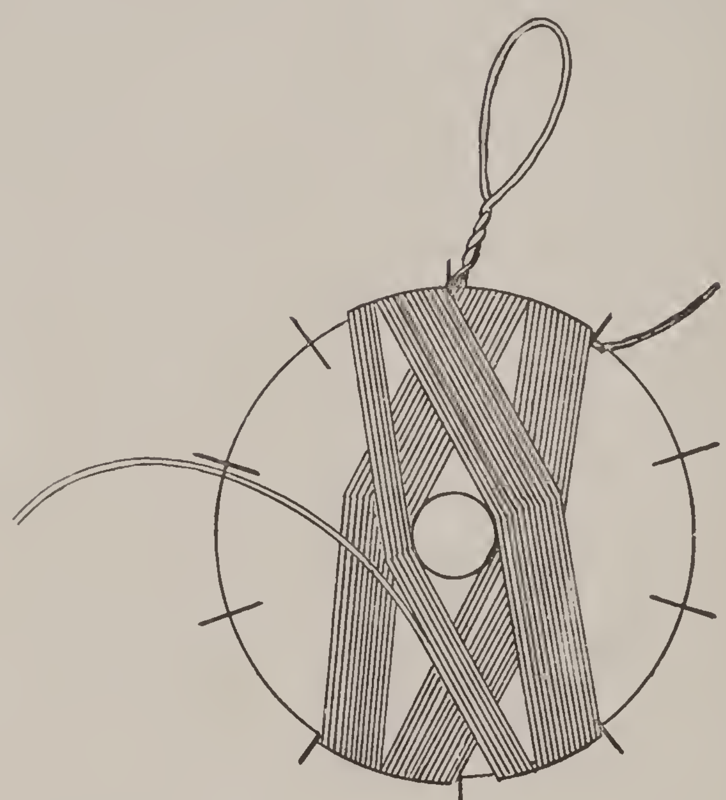


FIGURE 35.

ning a new coil cover the last one at the ends of the armature where it will be crossed by the new coil with a piece of cotton cloth, laid on with thin shellac. When you have wound on five coils you will have occupied each of the divisions. Give the wire you have wound on a good coat of thin shellac and cover it with a piece of cotton cloth. Now continue and wind over these coils five more in the same way, observing the same precautions, and when you have finished cut off the wire and twist the end with the free end of the first coil. Shellac the last winding thoroughly.

Our dynamo is intended to run at a pretty high speed, so to prevent the wires flying out by centrifugal force and rubbing

against the pole-pieces, we bind them down by half a dozen turns of thin brass wire at a third of the length of the armature from each end. In order that the brass wire may not cut through the insulation of the wire and short circuit it, we place two thicknesses of heavy brown paper where the binding is to

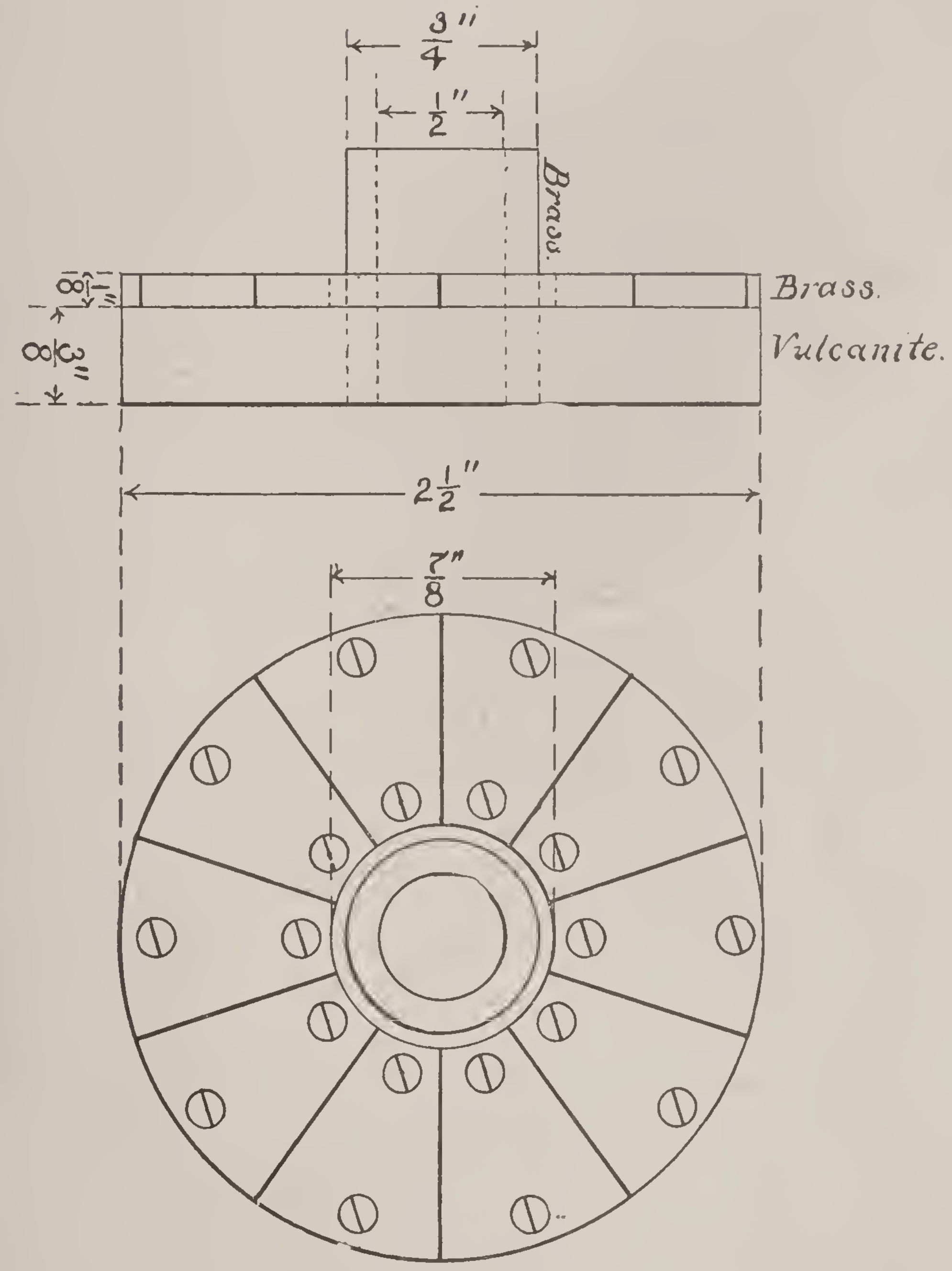


FIGURE 36.

be, and if mica is obtainable a thin layer of that, too, and then wind the brass wire on tightly; a dozen turns at each end will do, soldering the wires together every inch or so.

Next in order is the commutator. The backing should be made of vulcanite or fiber, but if this is not obtainable a piece of good hard wood, not liable to crack or shrink, can be made to do. If wood, it should be well paraffined.

Figure 36 gives the dimensions of the commutator complete. If the brass hub be knurled where it goes through the vulcanite

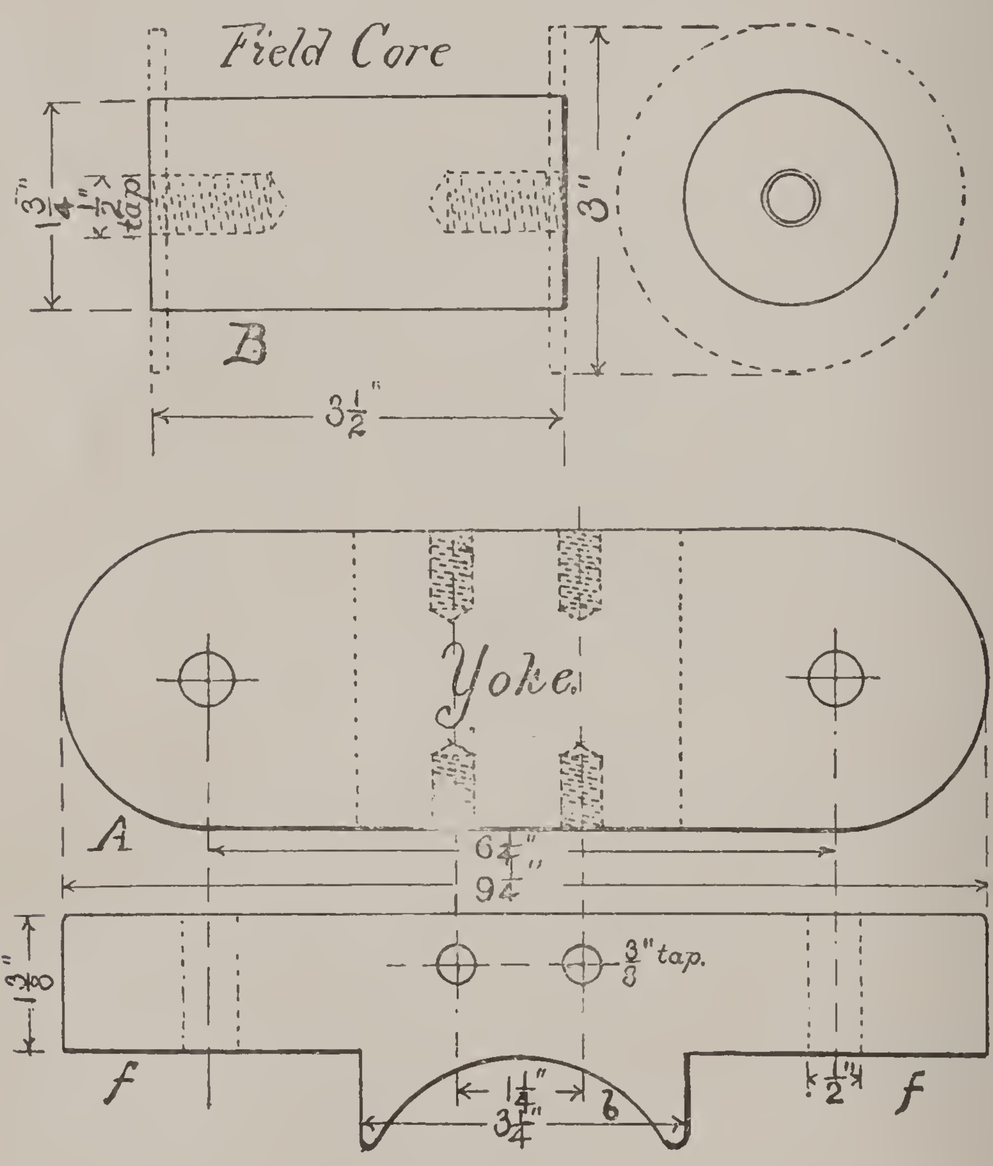


FIGURE 37.

it will keep it from slipping. A one-eighth inch machine screw through the brass hub will keep it from slipping on the shaft.

The commutator bars are made from a ring of brass, which is first screwed to the vulcanite backing by twenty screws, the

heads of which are countersunk just level with the surface of the brass. The ring is then cut radially into ten equal parts, while it is still screwed down. Put the commutator on that end of the shaft where the ends of the coils are left sticking out, and placing it with its end seven-eighths of an inch from the end of the shaft, and the segments of the commutator opposite the loops of wire, and set the set-screw; now pull one of the loops over the middle of the end of the bar opposite to it and cut it off so that it just reaches past the bar. Bare the ends of the wire and solder them together to the end of the bar. Do this with each loop and your armature is complete except balancing.

To do this place two straight edges in a horizontal position, leveling them carefully, and placing them at such a distance apart that the ends of the armature shaft will rest upon them. If it tends to roll to any one position it needs some more weight on the top side of the position where it comes to rest. Put on a little solder and repeat the operation until it will stay in any position on the straight edges.

The dimensions of the iron parts of the fields are given in Figure 37.

The pole-pieces *A* could be cast-iron, but the shape is so simple that they can easily be planed up from a slab of wrought iron, and will give much better results. The field-cores *B* are simply pieces of wrought iron turned to size and tapped for half-inch bolts. The faces *f f* of the pole-pieces and the ends *e e* of the field-cores which are to join them must be accurately surfaced. The diameter of the bore *b* was intentionally omitted, since no two inexperienced persons will wind an armature alike, and it would be impossible to predict exactly its diameter when

finished, and as the bore must be just large enough to allow the armature to revolve and clear. The diameter of the bore can best be found by calipering the armature.

The field-cores must have washers of some sort, preferably fiber, to hold on the wire. They should drive tightly on to the core and have an external diameter of three inches, and be one-eighth of an inch thick. Put one of these washers on each end of the field-cores, letting the core project just a trifle, say one-thirty-second or one-sixty-fourth of an inch. Insulate the core by wrapping two thicknesses of heavy brown paper around it between the washers. Bore a one-sixteenth inch hole through a washer on each core, close to the core and through this from the inside put six inches of the wire with which you are going to wind your fields. Bend it where it comes through to hold it, and putting the core in a lathe start it to revolving and wind on the wire. Be careful that it is wound on closely and tightly. After winding on one layer wrap a piece of paper around it and wind the next layer over this. Wind on ten layers of the same kind of wire you used for the armature. When you begin to wind on the next to the last layer, tie a piece of string to the first turn and let the ends hang out, and when you finish the last layer, before cutting off the wire tie the last turn down with the string, and cut the wire about six inches from the tie. Wind both fields in the same direction; we will say begin at the left-hand end and wind on the wire with the lathe running backwards. The supports from the ends of the armature should be cast of brass or moderately hard gun metal — under no circumstances of iron. The dimensions are given in Figures 38 and 39.

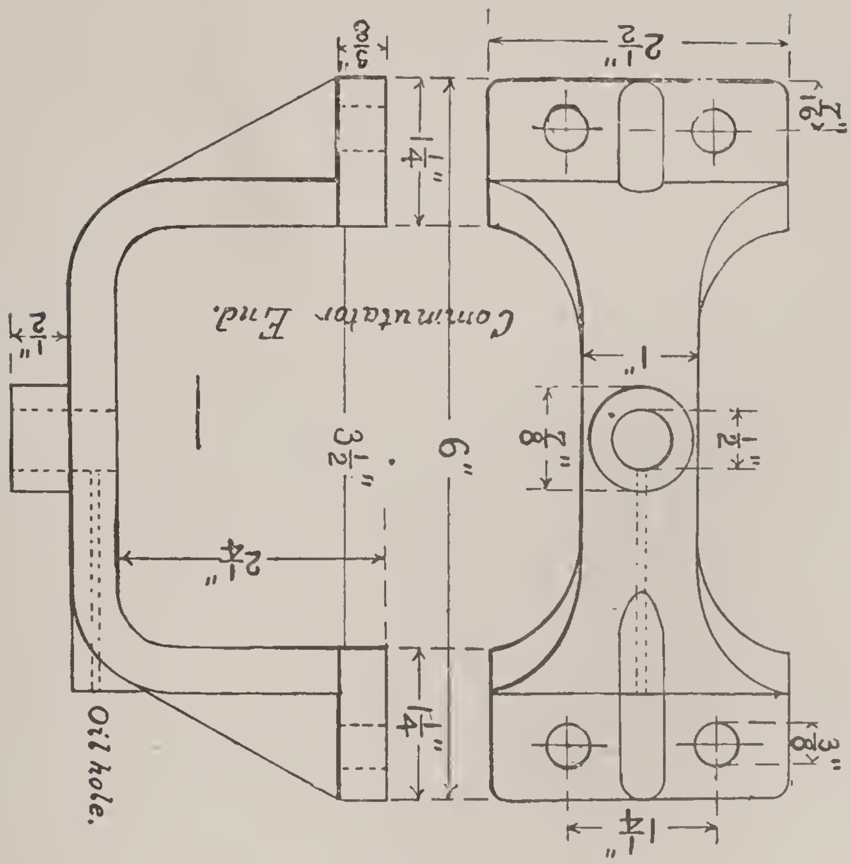


FIGURE 38.

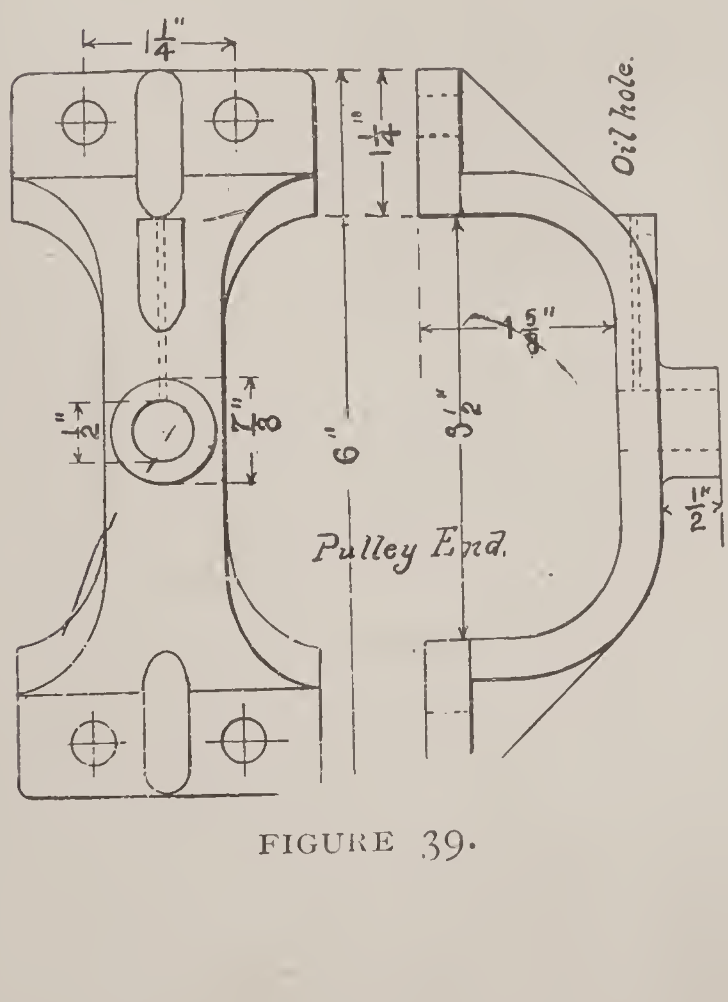


FIGURE 39.

An oil hole should be bored in each bearing and an escape for the waste oil below, so that it may not get upon the pole-pieces and thence to the armature.

The brushes and brush holder next demand our attention. The yoke had best be made of vulcanite or fiber, though good

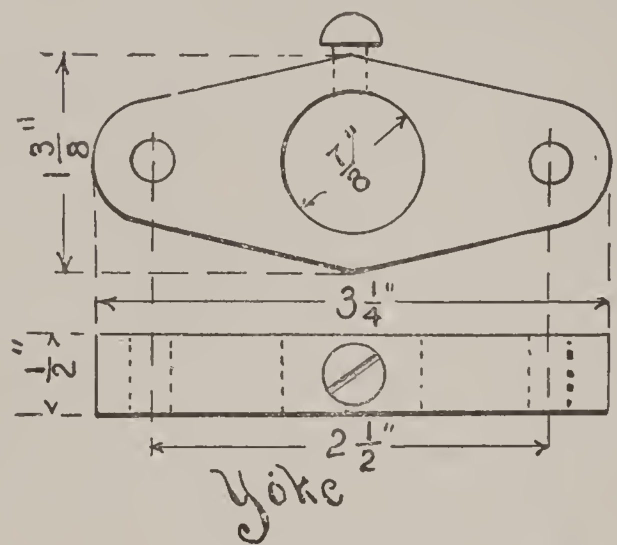


FIGURE 40.

hard wood will do. The dimensions are given in Figure 40.

The brush holders are shown in shape and size in Figure 41, and are to be made of brass.

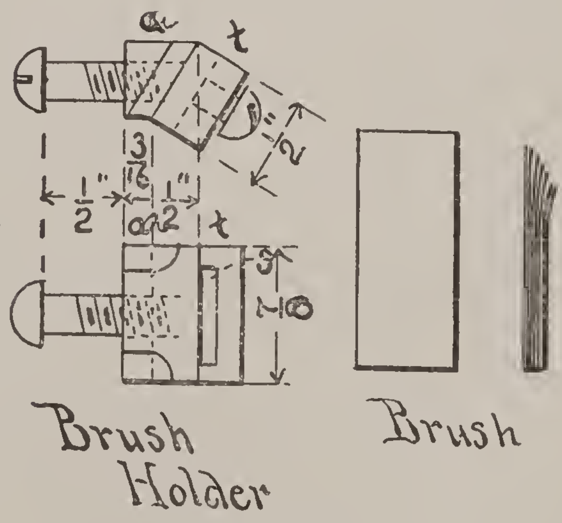


FIGURE 41.

The piece *t* is soldered to the part *a*, leaving the slot *s*, through which the brushes are passed and held by the screw.

The brushes themselves are strips of thin copper five-eighths of an inch wide and one and one-half inches long, three or four pieces going to make one brush, according to the thickness. They are soldered together at one end to keep them from slipping. The pulley is made of cast iron or brass, according to the dimensions given in Figure 42. A collar, to be placed

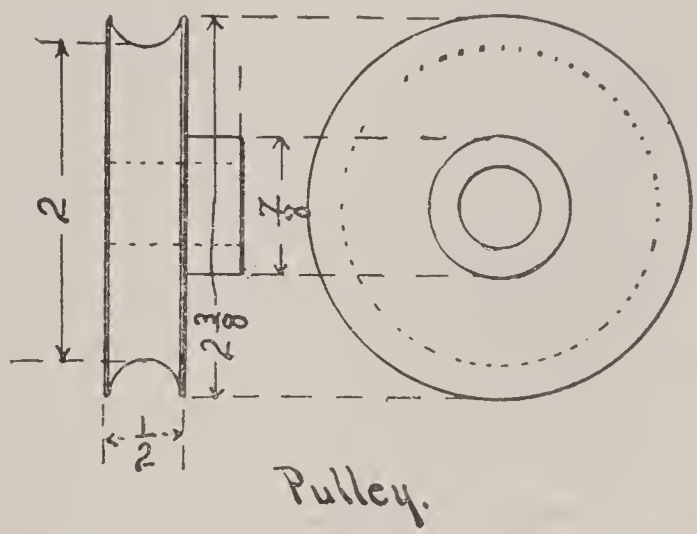


FIGURE 42.

between the armature winding, and bearing on the pulley end of the shaft, is made of iron one-fourth of an inch thick and three-fourths of an inch in diameter, and has a set screw to hold it to the shaft.

We are now ready to set up the dynamo. Bolt the bottom pole-piece to the ends of the fields where the wires come out. Let the inside wires of the fields come out on what you have decided to make the commutator side of the dynamo, and cut grooves in the bottom pole-piece for the wire to lay in. The wire should, by the way, be tapped where it touches the iron. Bolt on the top pole piece and one of the bearings. Put the armature in position and bolt on the other bearing. A wooden base 9 x 10 x 1$\frac{1}{4}$ inches should be provided and screwed

to the bottom yoke of the fields. On this, place six binding posts, two for the armature cable and one for each of the ends on the field winding. A diagram of the connections is shown n Figure 43.

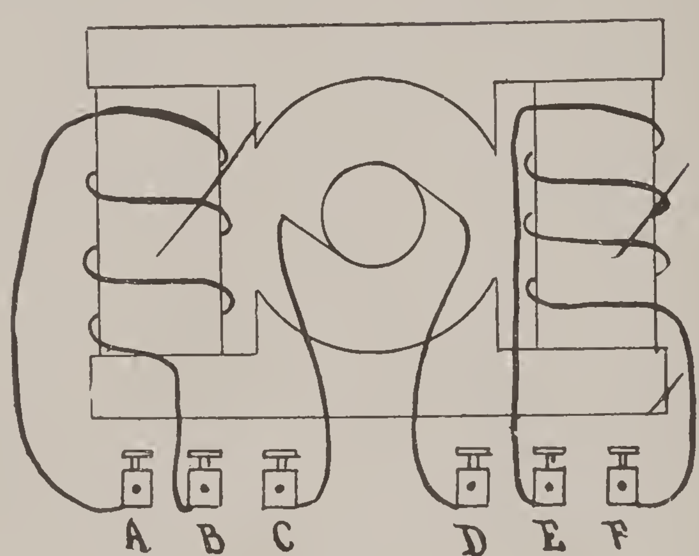


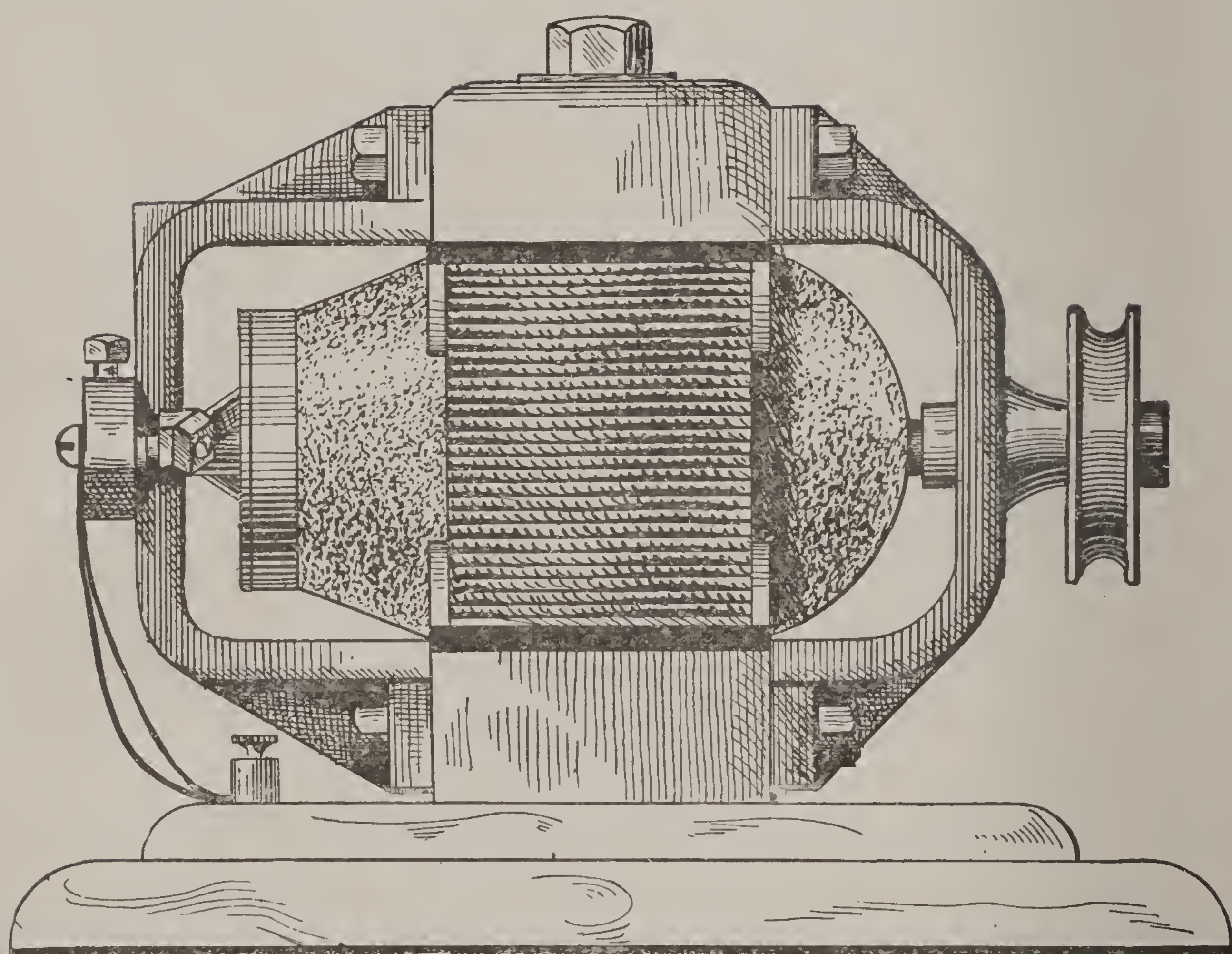
FIGURE 43.

Binding post A is connected to the outside end of the left field, B to the inside end, C to the left-hand brush, D to the right-hand brush, E to the outside end of the right-hand field, F to the inside end. The brushes should be connected to the binding posts by means of flexible cables. One strand of the twin conductor, such as is used to suspend incandescent lamps will do very well. The brushes should be set so that their ends bear firmly on the commutator. Turn the armature until one of the commutator slots is even with the end of one brush and set the brush so that its end is parallel with the slot. Then keeping the armature and brush yoke in the same position set the other brush in the same way on the opposite slot. It is important that the brushes be set accurately, for if badly adjusted there will be sparking at the commutator, which will injure both brush and commutator.

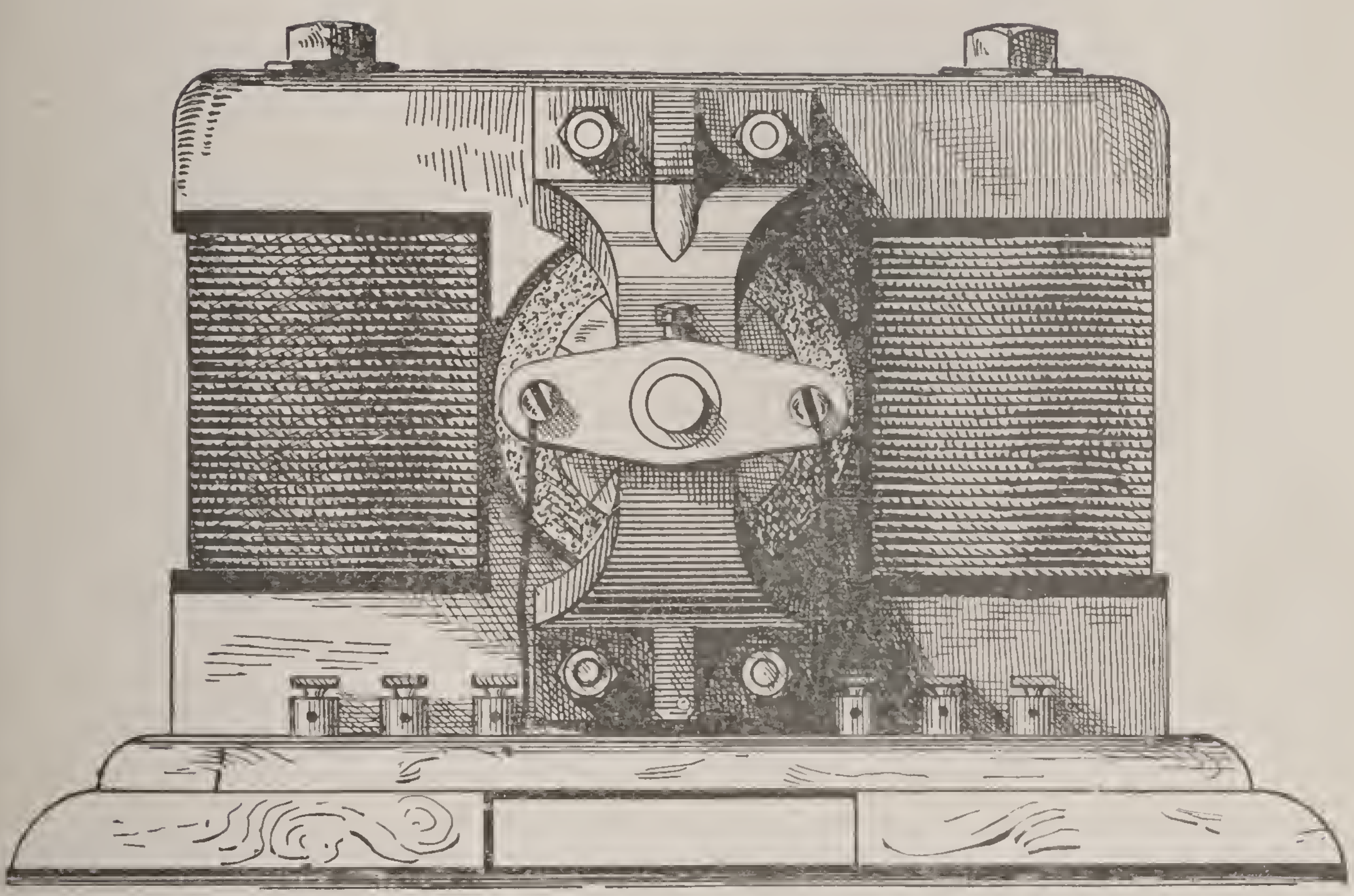
Before starting up the machine the fields must be magnetized. Connect the binding post B and E and put a current from a battery or other source of electric energy through the fields from A to F. Then remove the connection between B and E, and connect B to C and D to E. Belt your dynamo, to your source of power, and let it be run at a high speed, the higher the better within certain limits, say up to 2500 or 3000 revolutions a minute. If no other source of power is available, a sewing machine could be used by disconnecting the works from the fly-wheel and belting from that directly to the dynamo. The belt should only be tight enough to prevent slipping, as anything beyond this will waste energy in heating the bearings.

If you have a small steam engine the dynamo can be made to regulate, automatically, for a constant current, supposing your steam pressure can be kept constant. This is done by simply leaving off any governing device whatever from the engine and letting it run fast or slow, according to the demands of the dynamo. Of course nothing but the dynamo must be run from the engine. The dynamo must be run left-handed when you face the commutator. If the dynamo does not begin to generate immediately when the outside circuit from A to F is closed, gradually cut down its resistance until it does generate. Then shift the position of the brushes until there is no sparking at the commutator.

The method spoken of above for securing a constant current can be applied to running lamps in series. The lamps can be cut in or out of the circuit without changing the brilliancy of the rest, since the dynamo under the conditions given, is self-adjusting for constant current. It sometimes happens where a



DYNAMO—END VIEW.



DYNAMO—SIDE VIEW.

greater out-put from the dynamo is desired, that it is necessary to separately excite it. To do this disconnect B C and D E, and connect B E. Connect the battery or whatever you intend to use to excite the fields to A and F.

The battery should be capable of sending three or four amperes through the fields. The external circuit is run from the terminals C and D. The out-put can be nearly doubled by this method. This is also, the method to use where a constant potential is desired, but in this case the speed must be kept constant, and the engine or whatever supplies the energy, have some governing device. The current taken from the dynamo ought not to exceed five or six amperes. The circuit may go higher for short intervals, but it is not good practice to let it do so.

CHAPTER VIII.

HOW TO BUILD A ONE-FOURTH HORSE POWER MOTOR OR DYNAMO.

NO less accurate workmanship is required in the construction of a small dynamo than in one of a larger size. However, in this chapter is described a machine of such size and arrangement of parts as to be within the reach of amateurs' tools, yet capable of continuous and efficient service. It can be used as dynamo or motor, series, shunt, or compound wound, for any potential not exceeding 110 volts. Figures 44 and 45 show the complete machine in side and end elevations.

For convenience the description will be divided as follows:

1. Field magnet and frame.
2. Armature, shaft, and pulley.
3. Bearings.
4. Commutator.
5. Brushes, holders and yoke.
6. Winding.
7. Connections.
8. Testing and using.

The Field Magnet and Frame consists of two cast iron "pole pieces" united by a wrought iron "core". Referring to Figure 46-(b), it will be seen that the castings are apparently alike, but the patterns must be so made that the arms for supporting the

bearings will come on reverse sides, so that when the two are placed facing each other, both long arms will be on the commutator side and both short arms on the pulley side.

Provided with the castings, the holes for the core should be bored out smoothly to 2 inches in diameter. For doing this the castings may be either bolted to the traveling carriage of a lathe, and a boring bar inserted, or to a face plate, using a rigid inside boring tool. If possible finish with a reamer. Drill, tap and counter-bore for the seven-sixteenths inch screw "a" on the bolt and screw list, Figure 47. The slots at the bottom, which may well have been cored part way, can now be extended through with a hack saw. The core is to be of wrought iron, seven and three-sixteenths inches long, smoothly turned to two inches in diameter. If what commonly known as "cold rolled" steel is available, no turning will be necessary. This quality of steel is very soft and quite as good as wrought iron for magnetic purposes.

Put one pole piece on the core, tighten the clamping screw; drill a one-fourth inch hole through the cast-iron into the steel and drive in a steel pin about three-fourths inch long. These two parts will then be permanently attached. Slip on the other pole piece, see that the protruding arms are parallel, tighten in place, and drill a one-fourth inch hole in the end, so as to be half in the core and half in the pole piece, in the location as shown, and drive in another pin. This method locates the two parts definitely, but allows easy removal of one pole piece for placing the field spool.

The boring of the ends of the arms and the field may now be done. Bolt the structure as now assembled to the carriage of a screw cutting lathe. With a boring bar between

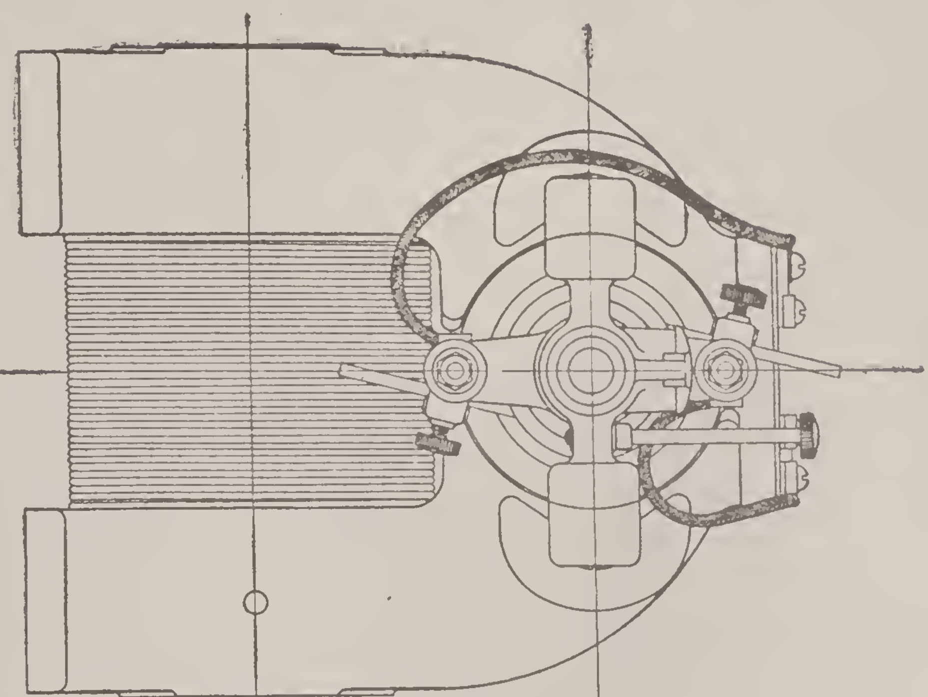


FIGURE 44.

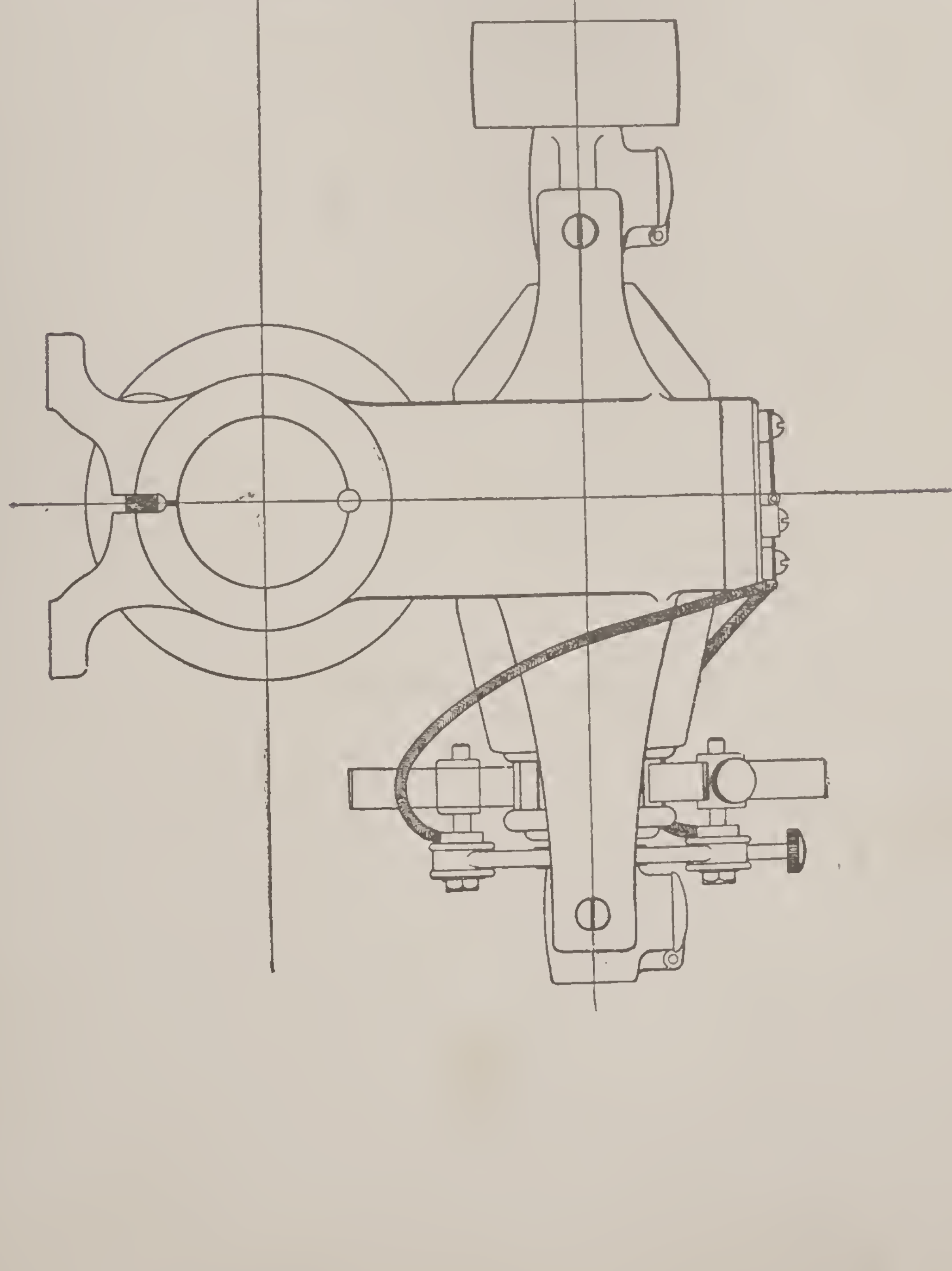


FIGURE 45.

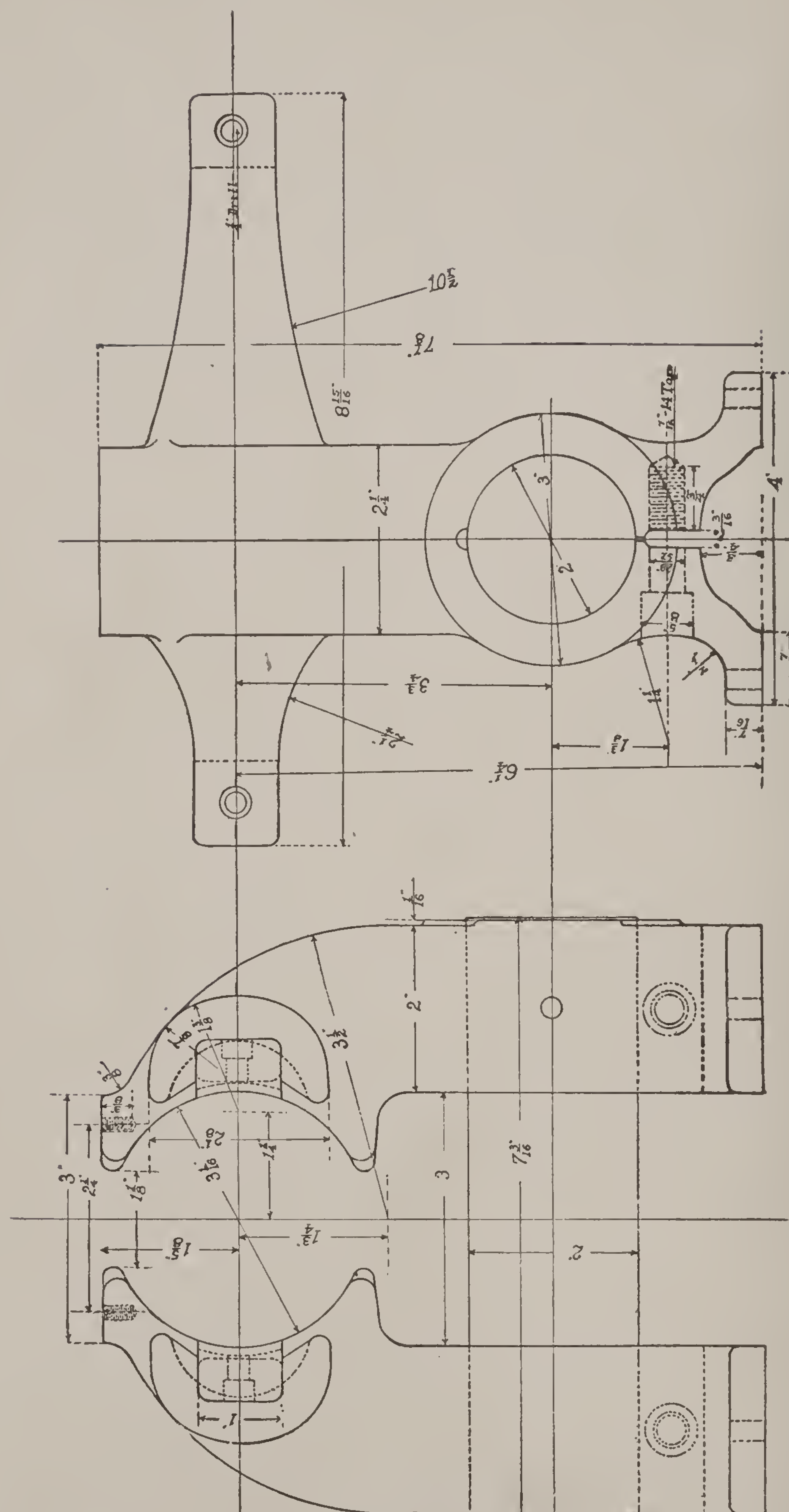


FIGURE 46 (a).

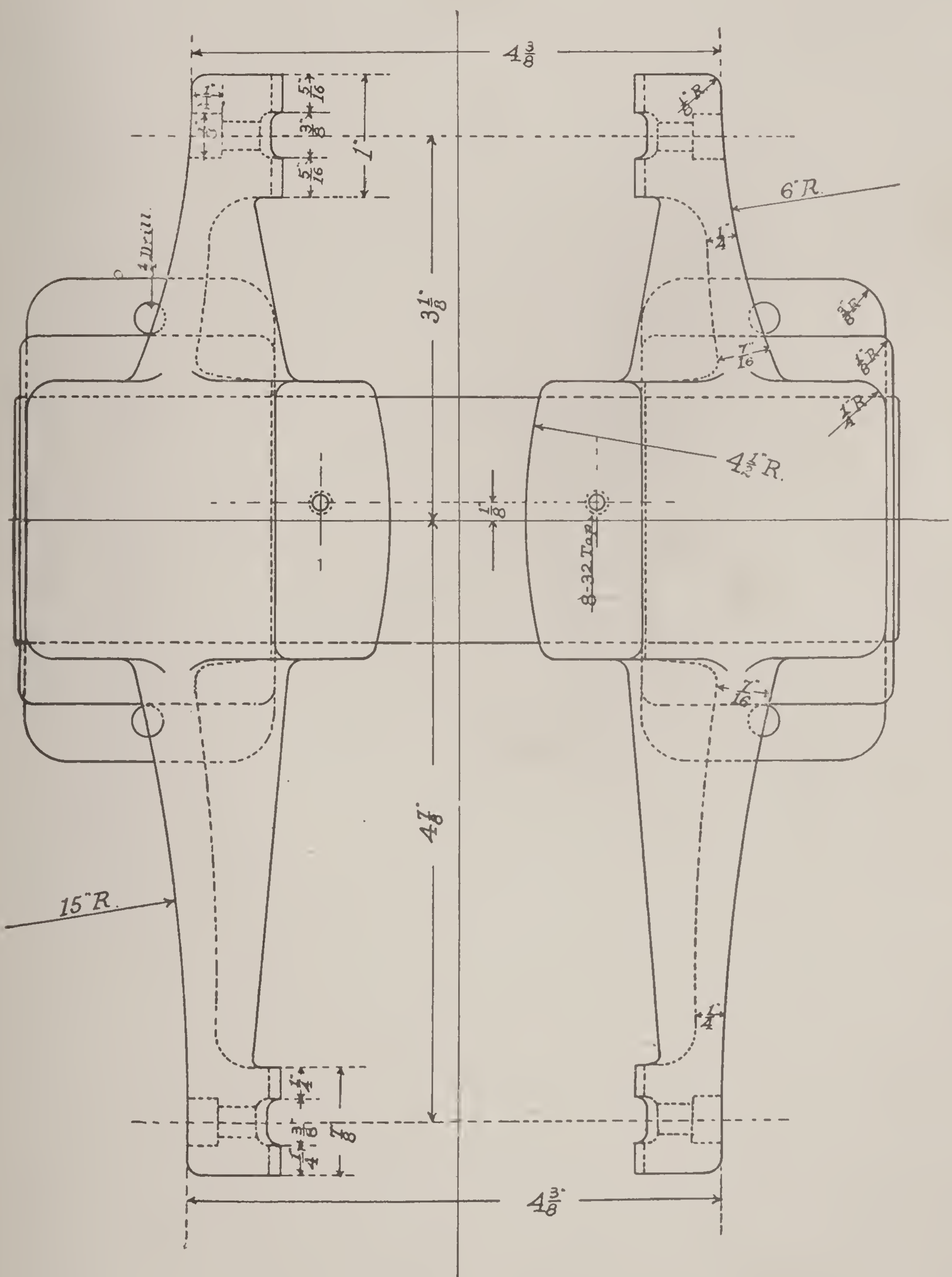


FIGURE 46 (b).

centers, take first a slight chip, at slow feed. If carefully done, there will be no danger of breaking off the arms, but if convenient some sort of supports can be devised to brace the long ones. The finished diameter should be three and one-sixteenths inches. Drill and counterbore the holes in the arms for screws "b"; drill and tap the two in the top for screws "c"; drill the four in the feet for screws "d". The removal of sharp corners

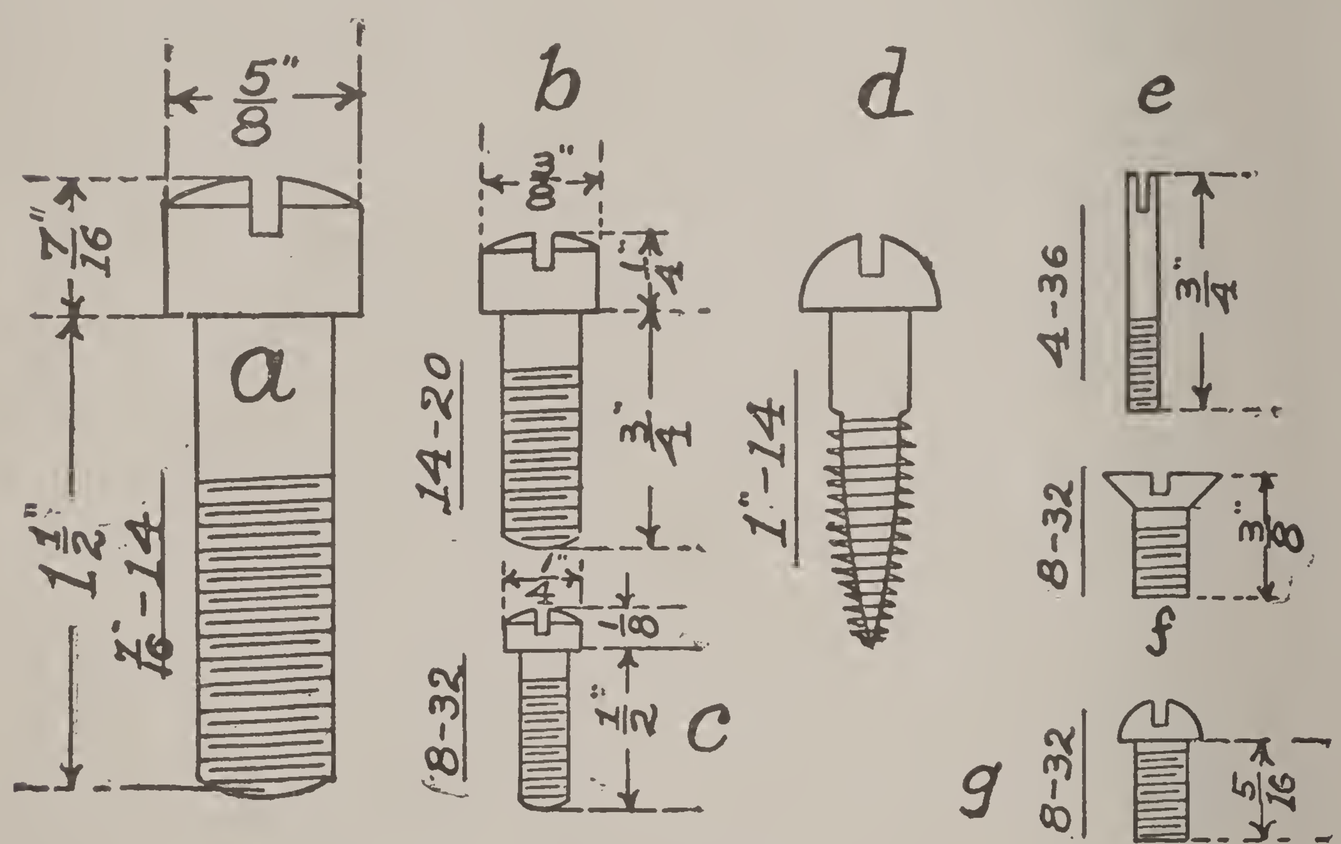


FIGURE 47.

or fins on the castings will complete the machine work on the field magnet.

Armature, Shaft and Pulley. The armature is of the toothed drum type, built up of laminations of sheet iron. Figure 48, *a*, shows one of these sheets. If punchings of this description cannot be otherwise obtained, the builder may proceed as follows: From stove pipe iron cut three and one-eighth inch squares. Enough should be cut to make a thickness two and one-fourth

inches when tightly clamped together. Cut the corners so as to make the sheets octagonal. Clamp them between plates of one-fourth or three-eighths inch iron and drill a five-eighths inch hole as near the center as possible. Put in a short five-eighths inch turned bolt and screw on the nut. Remove the other clamps and turn the mass to a diameter of three inches.

Without disturbing the center bolt, put the cylinder thus formed in a milling machine or gear cutter and saw out the the sixteen slots as shown, one-fourth inch wide and three-eighths deep.

Part of the work on the shaft may now be done. Procure a suitable length of cold rolled steel, five-eighths inches in diameter, center it in a lathe, with the aid of a back rest, and turn it, excepting the space three inches long in the centre, to nine-sixteenths inch in diameter. On the ends of that space cut 27 threads per inch for a distance of three-eighths inch. Cast-iron flanges or "heads," for screwing on these threaded portions, are clearly shown at "*b*," Figure 48. Screw one of these tightly in place and slip on the punchings. It will be necessary to put a piece of iron or brass one-fourth inch thick and about three inches long in one of the grooves in the sheets, to keep the teeth matched. With this bar still in place, tightly screw on the other head, using a spanner wrench with pins engaging in the two small holes as shown. By oiling its surface and threads, this may be easily done without allowing the sheets to slide on each other. Replacing the armature in the lathe, it will probably be found that the shaft does not run true; this is due to the fact that sheet iron cannot be procured of an exactly uniform thickness, and the shaft has had to bend to compensate for the difference. With a lever

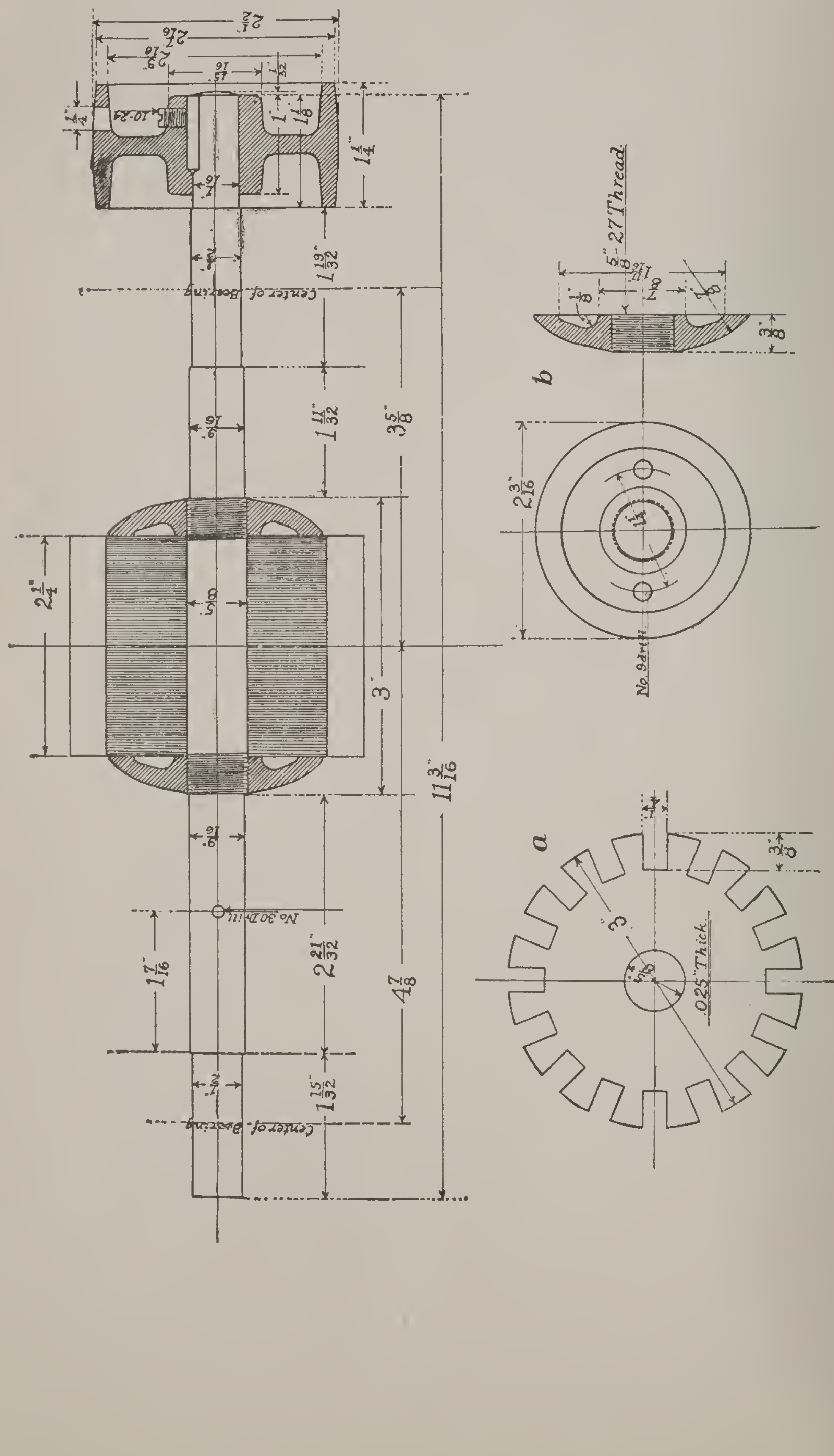

10-24
Center of Bearing
No. 30 Drill
Center of Bearing
5/8"-27 Thread
b
a
.025" Thick.

FIGURE 48.

spring the shaft until it runs true, and complete the turning to the required dimensions. Leave the portions for the bear-

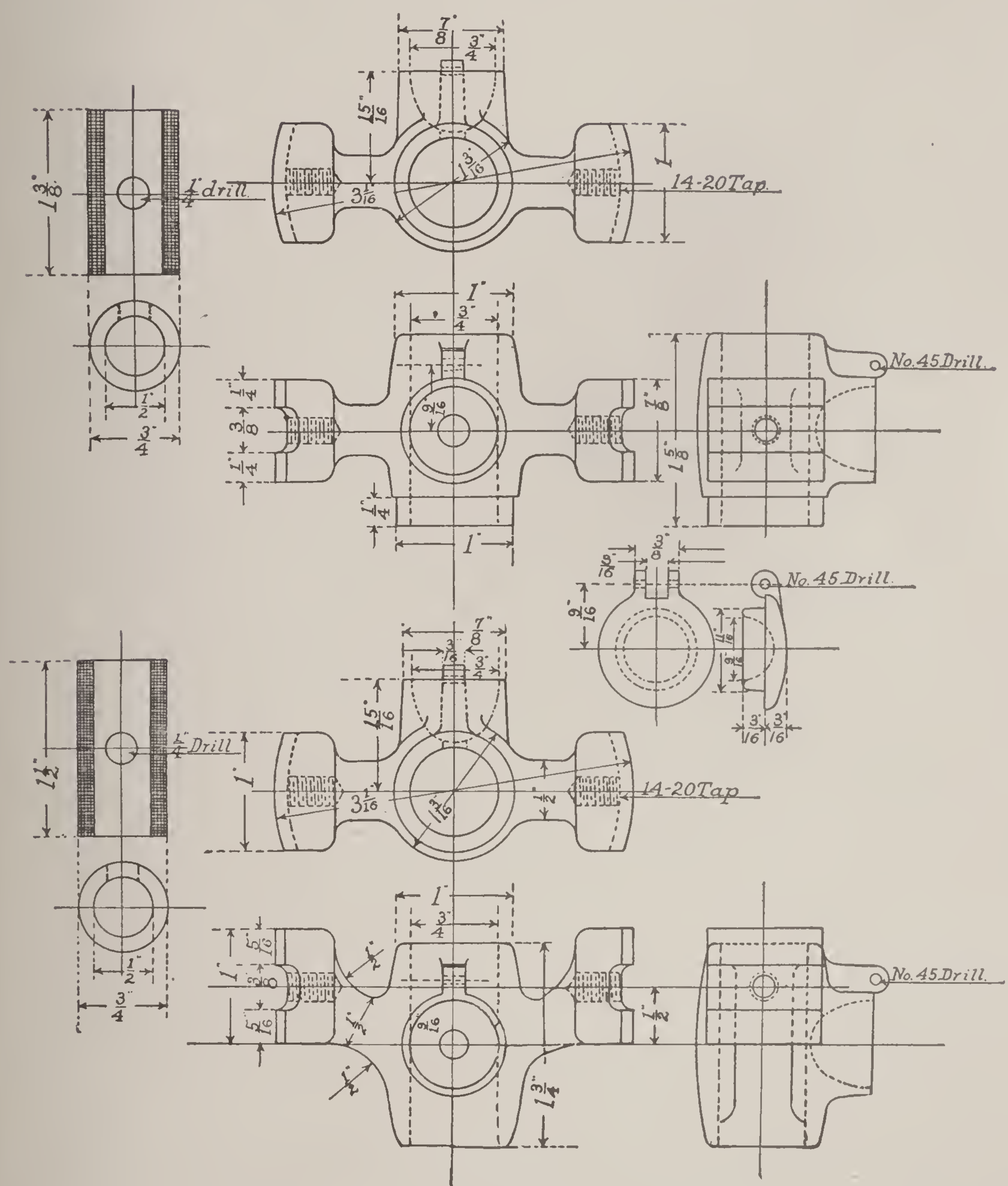


FIGURE 49.

ings about one-hundredth inch large to allow for final fitting. Put in the small pin for holding the commutator in position.

After turning and fitting the pulley, a No. 30 drill may be run in on the end, half in the pulley and half in the shaft. Use a piece of one-eighth inch steel wire for a key and so locate the set screw as to hold the key in. Figure 48 shows the completed structure.

Bearings. In order that magnetism may not be diverted from its useful path, the bearings should be of brass, or some similar material. The construction of these is given in Figure 49. For the pulley end a longer bearing is provided than for the commutator end, and the center so located as to carry the pulley at a safe distance from the ends of the arms. Proximity would encourage leakage of magnetism.

Chuck the castings, bore out the cored holes, and ream to three-fourths inch in diameter. Mount them on an arbor and turn the ends to three and one-sixteenths inches in diameter and on the commutator end casting cut the straight portion for the yoke bearing one inch in diameter for a distance of one-fourth inch. Lay on the oil-well covers and drill for the pins on which they hinge. Set the bearings in position between the ends of the arms; it will ensure their alignment if a three-fourths inch arbor is inserted, long enough to extend through both. A one-fourth inch drill may be run through the previously drilled holes in the arms for about one-eighth inch into the brasses. Drill one-half inch further with a No. 8 drill and tap out 14-20. The screws "b" may now be inserted and arbor removed.

Quite a variety of materials are suitable for the bushings or "linings" for the bearings. Brass, gun metal, graphite, cast iron, babbitt metal and lignum vitae are used. Gun metal is in good favor. Drill out the castings, ream them to one-

half inch in diameter, mount them on an arbor, turn the outside and ends to size. The oil groove may be cut with a round-nosed hand tool. It will be noticed that the linings are

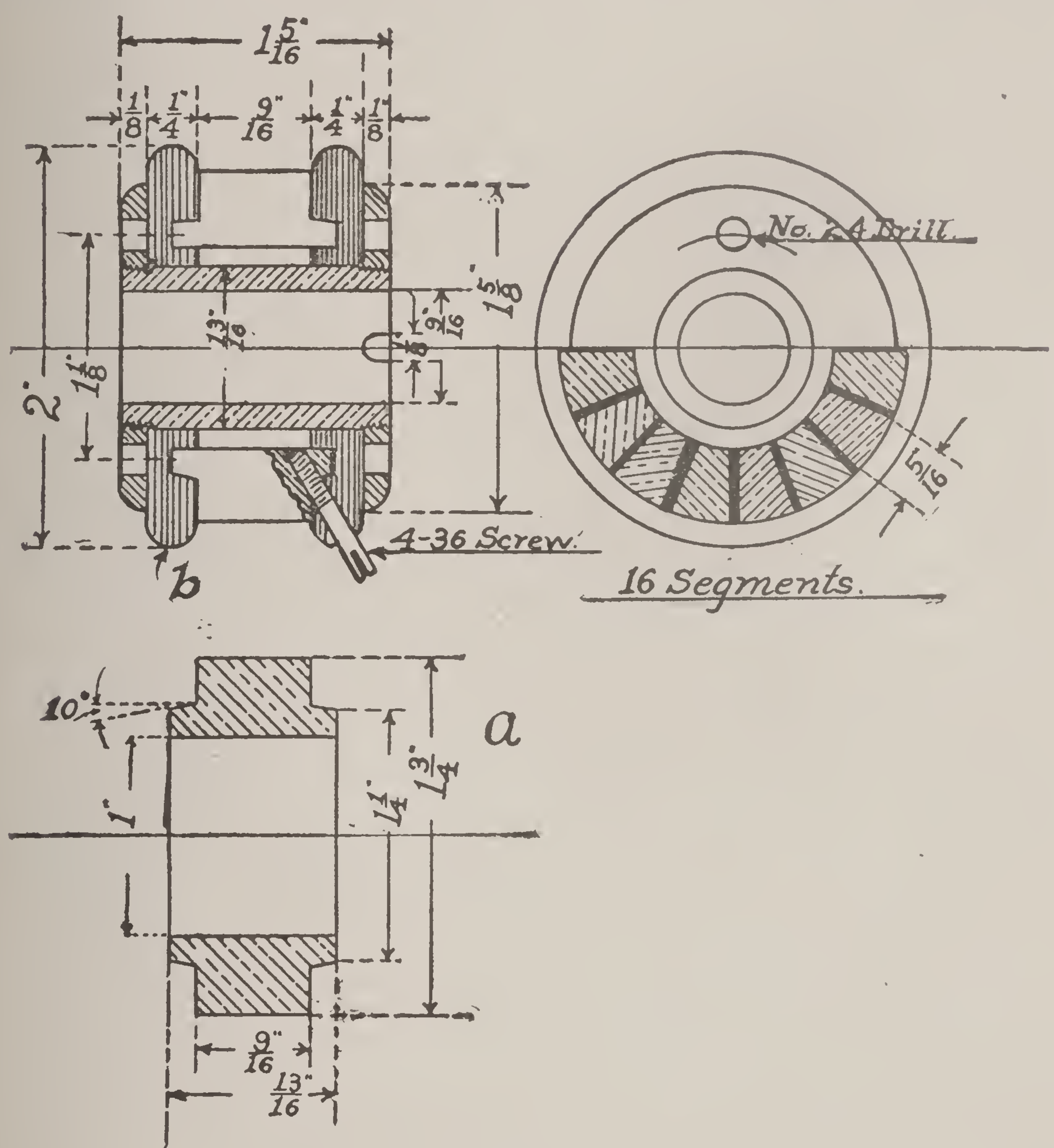


FIGURE 50.

shorter than the castings into which they are to be forced. The purpose is to provide a surface for catching the oil that may be thrown from the shaft while running. Locate the linings so as to bring the armature in center of the field, and

allow about one-sixteenth inch for end motion; then drill through the bottom of the oil-wells and insert short pieces of brass tube. When occasion requires the removal of the bushings, these tubes may be driven entirely through and out of the way.

Thick grease of about the consistency of lard is to be used for lubrication, and a little will last a long time. The warmth of the bearing will melt just enough grease to ensure proper oiling.

Commutator. The construction of a commutator is often a Waterloo to an amateur, but the one here described is compact, durable and well insulated. A comparatively small lathe and easily obtained materials will suffice for its construction. There are sixteen divisions, or "segments," made of smooth copper, drawn wedge-shaped, or of filed castings to fit around into a complete circle; or a ring may be turned to the right size and then split into sixteen parts. The latter may be the more available method.

Procure a piece of copper tube, or gun metal casting, that in the rough measures about one and seven-eighths inches outside diameter, fifteen-sixteenths inch inside, and seven-eighths inch long. Bore out the inside to one inch in diameter, mount it on an arbor and turn the outside to the dimensions shown at "a" in Figure 50. While still on the arbor, place it in a milling machine, slotter, or gear cutter, and saw it into sixteen segments. Let the saw be thin and cut within one-thirty-second inch of the arbor. Fit strips of mica to the saw cuts, then finish cutting the segments apart. File off the burrs and assemble the segments and insulations into a circle. Secure them with a string or rubber band, and prepare the rest of the structure.

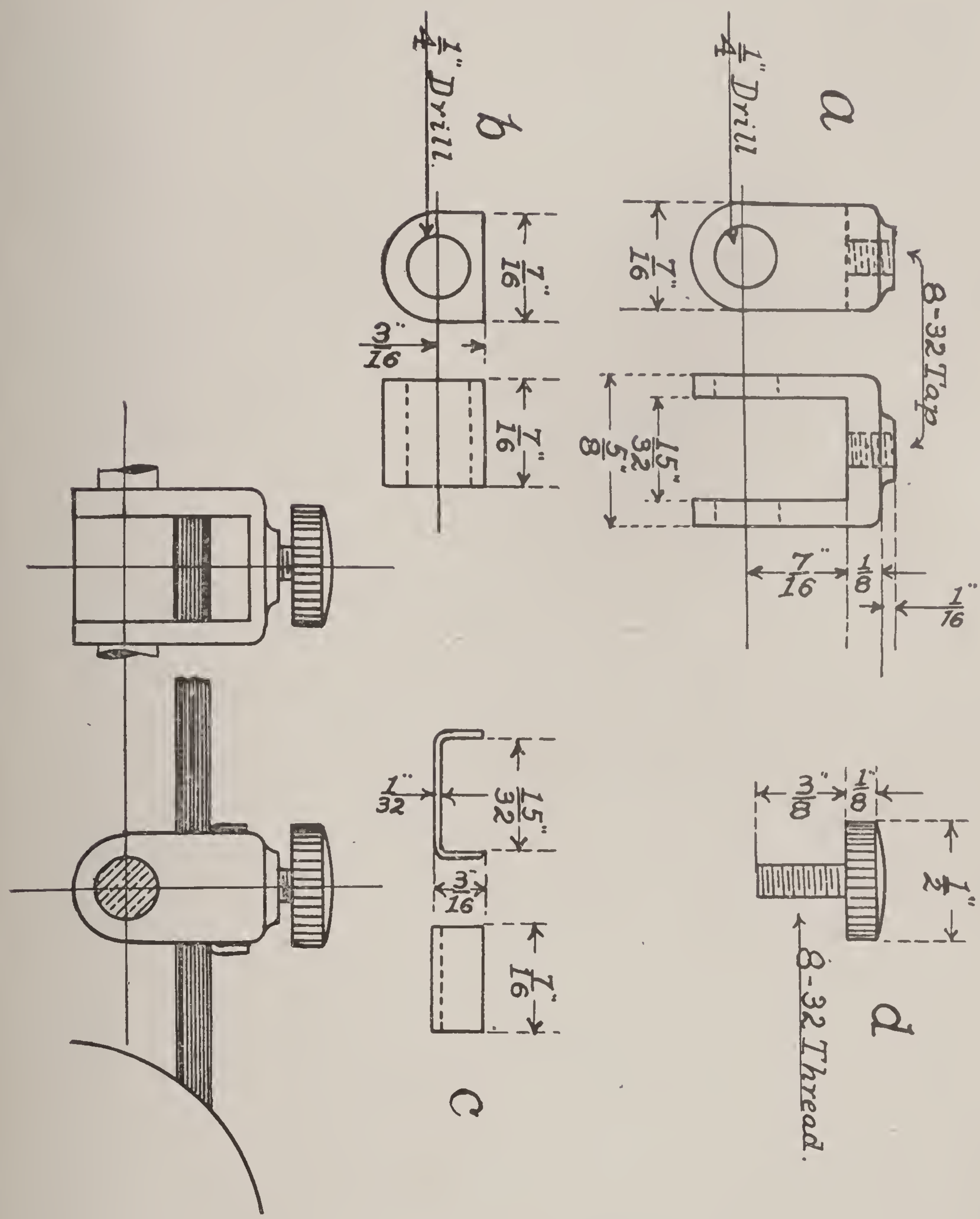


FIGURE 51.

A piece of seamless brass tube, one and three-eighths inches long, three-fourths inch outside and nine-sixteenths inch inside diameter is to be threaded for a short distance at each end. Use a fairly fine thread, say twenty to the inch. File a slot one-eighth inch wide in one end to fit the pin that was located in the shaft. Tap two iron or brass nuts to match. Drill two holes in these thin nuts to allow the use of a spanner wrench. Screw one of these on tightly. Turn two vulcanized fiber discs as shown at "b" in Figure 50, and slide one on the brass tube; set the segments into the grove; put on the other disc, and screw on the other nut, but be careful not to let the segments get "skewed" or strained into a spiral.

Provision must now be made for getting electrical connection between the segments and the wires that are to be wound on the armature. Insert an arbor in the commutator and tilt it on a wooden jig or frame to an angle of about 15 degrees. Prick-punch into the fiber. in sixteen places opposite the centers of the segments, and drill through the fiber with a No. 32 drill; then continue through the segment with a No. 40 drill, and thread with a 4-36 tap. Brass rods, threaded 4-36, "e" Figure 47 may be screwed into these holes, care being taken not to let them extend through the segments and touch the tube. Bind some copper wire tightly around the segments to hold them in place, and remove the nut from the end farthest from the connection screws; take off the disc and clean out the chips of copper that may have collected. Reassemble the parts, remove the binding wire, and turn the surface of the segments even, finishing with a piece of fine sand paper.

5. *Brushes, Holders and Yokes.* Two kinds of brushes are commonly used, copper and carbon, with appropriate holders.

The same supports called "yoke and studs" will fit either. For the former, "planished" or hard rolled leaf copper about five-one-thousandths inch thick is to be cut in strips seven-sixteenths inch

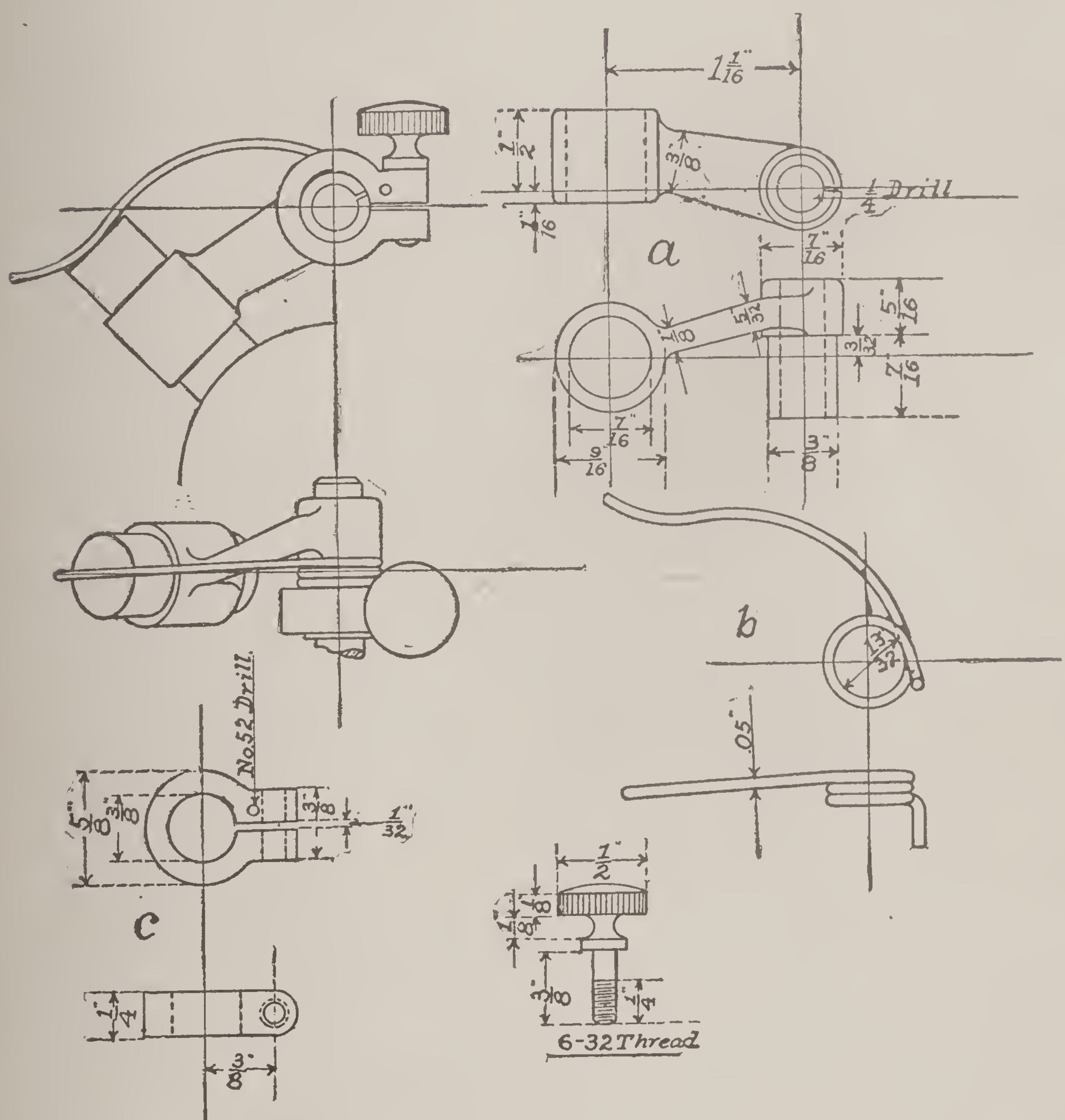


FIGURE 52.

wide and two inches long. Enough to equal one-eighth inch thickness should be grouped together and soldered at one end, the other bevelled to an angle of 45 degrees, to fit the commutator. The holder is shown assembled and in detail in Fig

ure 51. There are two brass castings, a body "a" and shoe "b"; a clamp "c" of sheet copper, and thumb screw "d" of brass. The construction is such that the pressure of the screw binds both the brush and the holder securely. A slight loosening of the screw will allow the holder to be tilted, and remove the brush from the commutator, without changing the adjustment.

A suitable carbon brush holder is given in Figure 52. The brass body casting "a" is drilled at one end one-fourth inch in diameter, the same as the copper holder, but the other end is drilled seven-sixteenths of an inch. A presser "b" is made of steel or brass wire about five one-hundredths inch in diameter. The clamp "c" is also a casting, and serves to retain the short end of the spring. By turning the clamp one way or the other a variation of tension on the spring may be obtained, and the screw binds it and the holder in any desired position on the stud. The brush is itself a short piece of standard electric light carbon, with one end filed to fit the commutator the other with a groove for keeping the presser in place.

Make the brush holder "studs" of one-fourth inch brass rod. See "a" Figure 53. One end is turned to three-sixteenths inch diameter and threaded 10-24. For the flange, a brass washer may be slipped on the three-sixteenths inch portion, soldered and turned true. "b" and "f" are brass, the washers "c" and bushing "d" are hard rubber; terminal clip "e" is sheet copper.

It is necessary to provide some means of adjusting the position of the brushes. This is accomplished by attaching the studs to a rocker or "yoke." The construction is shown also in Figure 53. Bore out the center of the casting to fit on the turned portion of the bearing as previously noted; drill and tap

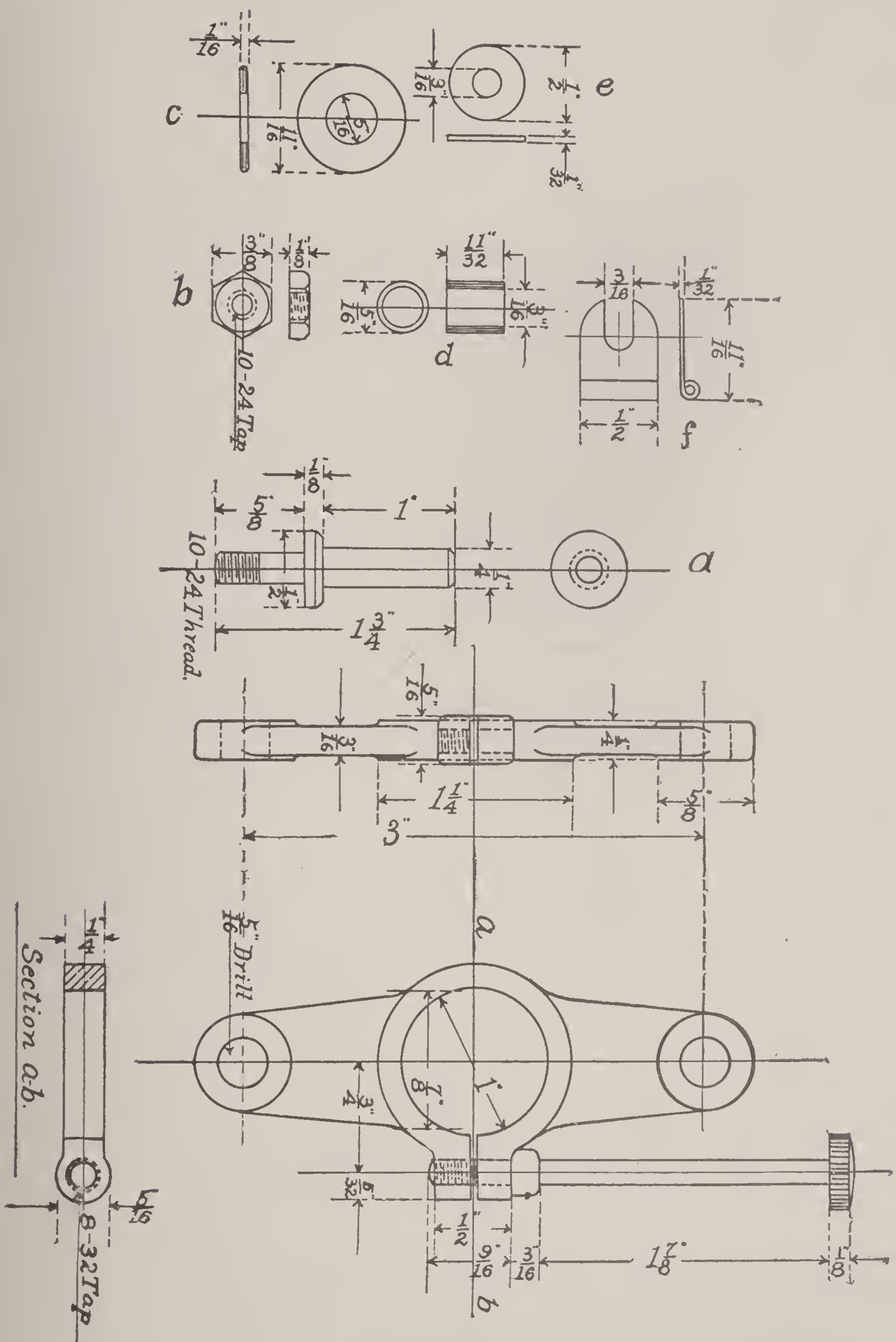


FIGURE 53.

for the thumb screw, and then saw the slot. The rounding ends should be finished so as to allow the studs to be firmly held and kept parallel with each other.

Winding. Having completed the general mechanical parts of the machine, the builder will be ready for the more purely electrical. Preliminary to the placing of the wire, there must be the uninteresting work of suitably insulating the core. An amateur is liable to slight this part of the work.

The winding easily divides itself into the two separate portions,—armature and field. Just what sizes of wire to use will depend on the voltage and current desired, but the same general directions will answer for all. As the running of incandescent lamps is a common application of even small dynamos, a winding for lighting three standard 50 volt lamps will be explained in detail, and sizes stated for various other potentials.

First, insulate the core; sharp corners are to be filed off, and a thin coat of shellac put on, extending along the shaft also for one and one-half inches. Wind several turns of thin, tough brown paper around the shaft, gash the paper a little so that it will lap up on the heads for one-eighth inch. Cut a number of discs of paper three and one-eighth inches in diameter with five-eighths inch hole, and some strips two and one-half inches wide of indefinite length. Slip on a disc over each head and shellac it on. When dry make a single radial cut between the teeth with a pair of scissors and turn the edges of the paper over the corners into the grooves. Start the strip of paper in the bottom of a groove, and pass it over a tooth into the next groove; press it well into the corners with a thin strip of wood, and then press it down into the next groove, and so on

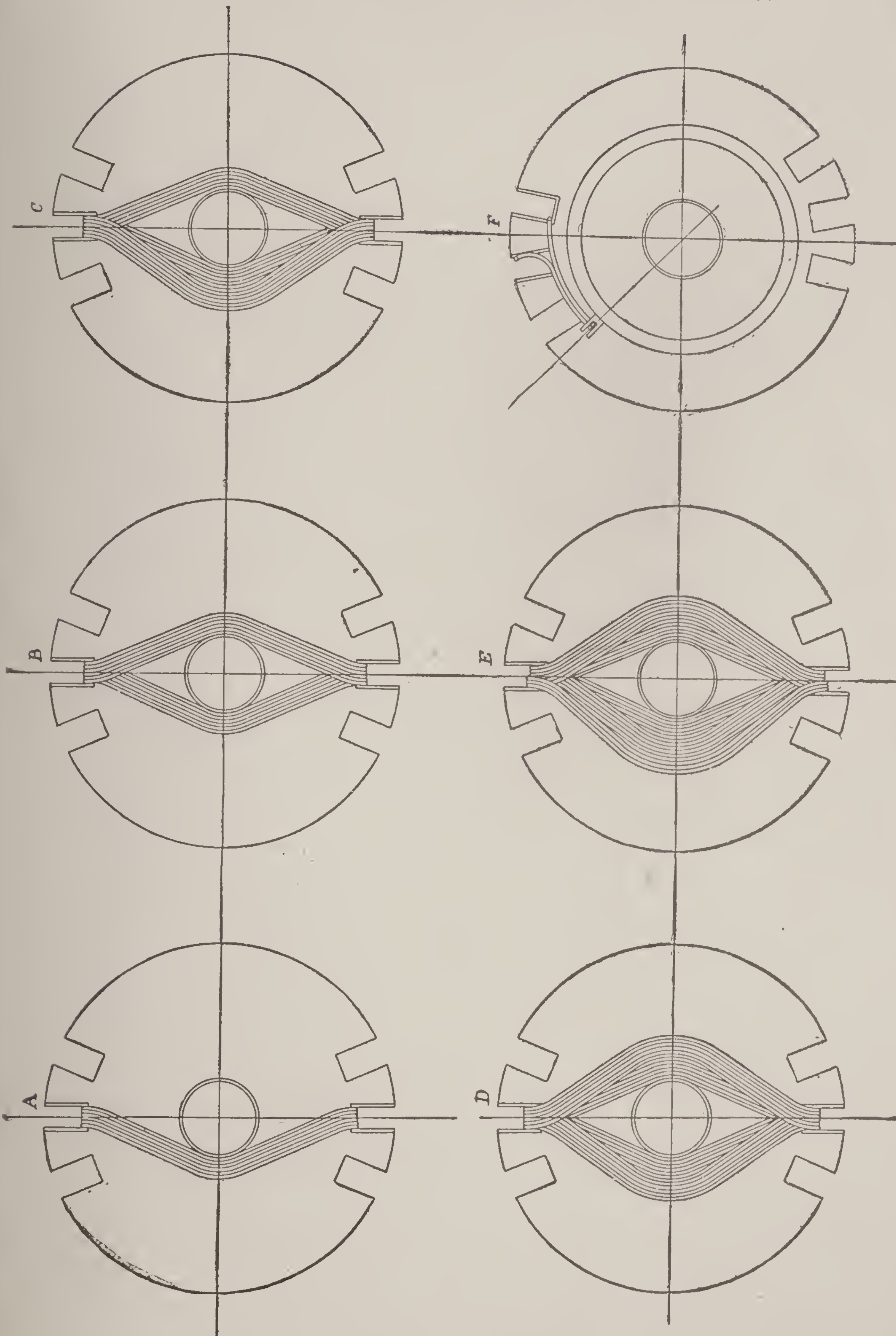


FIGURE 54.

around the core to the starting place; cut the paper, but do not lap the ends. Slit the overhanging edges and bend them so as to cover any exposed iron. Put another disc on the heads, slit and bend over their edges as before; put another strip all the way around the core, in the grooves, but be careful to have the joints always in different places in successive layers. Four layers everywhere will be a sufficient amount. The paper should occupy only so much space that a three-sixteenths inch strip can be forced down into the insulated grooves. Use thin shellac freely as an adhesive and do not allow the paper to "pucker" anywhere.

Provide a continuous coil of about one and three-fourths pound No. 22 (twenty-five one-thousandths inch in diameter) double cotton covered magnet wire. Rest the armature between lathe centers or on other convenient support, so as to be turned back and forth as the winding progresses. Lay the starting end of the wire through one of the grooves toward the commutator end. For the moment it may be twisted around the end of the shaft. Carry the continuation of the wire across the head at the pulley end, giving the core a half turn so as to bring the opposite groove on top; lay the wire in this groove but leave enough room in passing the shaft to allow for five more turns. Cross the head at the commutator end, at the same distance from the shaft back to the starting point, rotating the core back to its original position. Lay a second turn beside the first, then a third, and so on until six turns are on. This should make just one layer in the grooves. The wires may be smoothed down and firmly pressed into position with the aid of a chisel-shaped piece of soft wood. If the wires bulge a little in the grooves, pull them further away from the

shaft, thus drawing them tight in other places. If sufficient room has not been allowed to get all the turns in past the shaft, a little stretching of this kind may provide space. Shellac these six turns and let them dry. "A", Figure 54, shows this

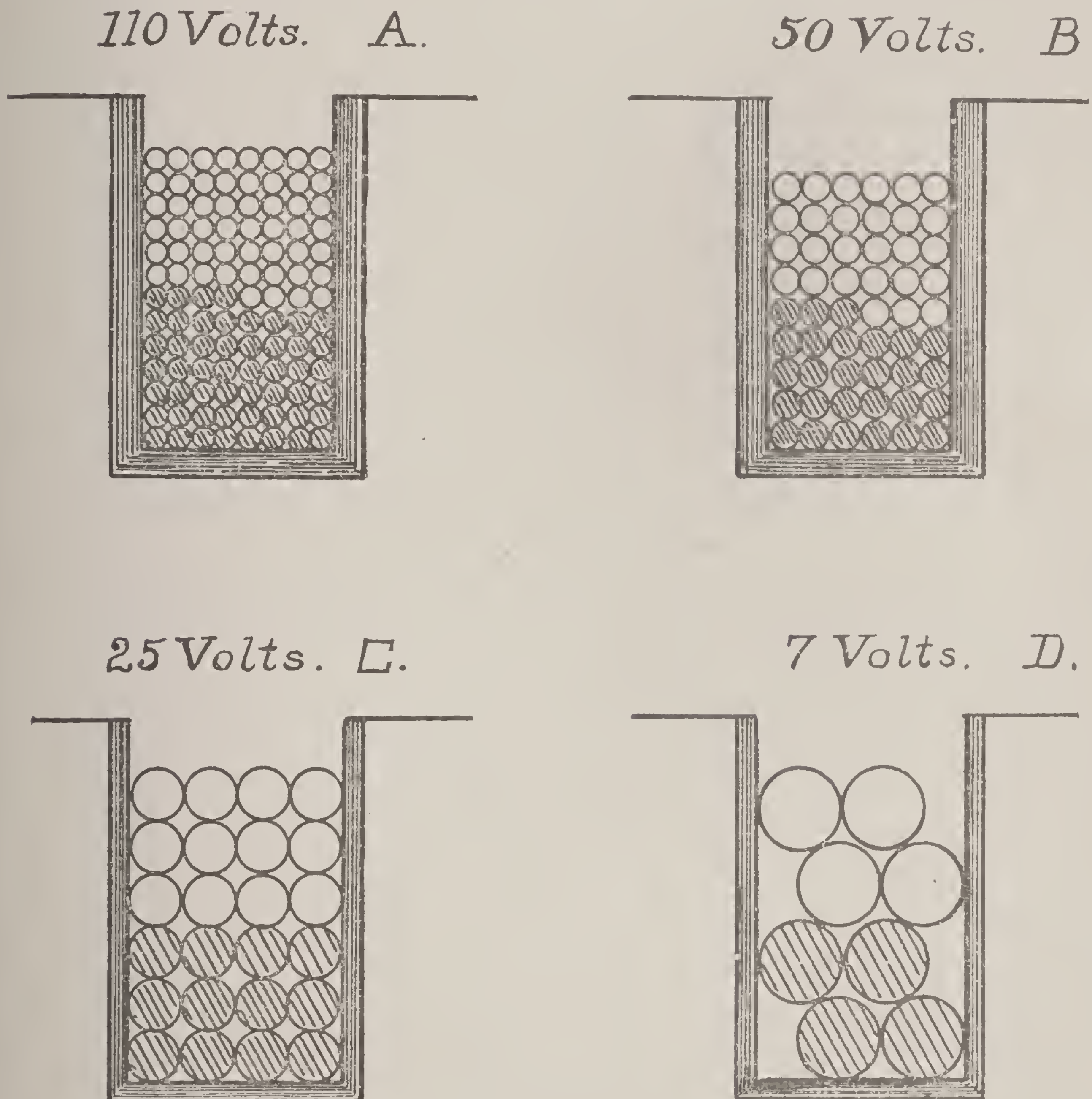


FIGURE 55.

first layer. Continue the winding in a second layer, and place six turns on the other side of the shaft. "B", Figure 54, shows this stage. Shellac again and when dry, wind on a third layer of six turns, passing the shaft on the same side

as the first layer, only further out. See "C" Figure 54. A fourth layer goes on the other side, as shown in "D", and also a half layer of three turns,—"E". Make a loop in the wire about three inches long, twist the two together and lay the continuation in the groove next to the starting point. There will now be two slots a little less than half full of wire, and the twenty-seven turns will be so spread over the ends of the armature as to be but one layer deep where they pass the shaft. Wind twenty-seven turns in the next slot and its opposite. These wires will cross the first wire at a slight angle; bring out a second loop and wind twenty-seven turns in the third slot and its opposite, and so on around until each of the slots have twenty-seven wires in them and eight loops are made for connecting to the commutator. Continue a ninth coil of twenty-seven turns on top the first coil; bring out a ninth loop, and wind a tenth coil of twenty-seven turns on top the second coil, and so on until the sixteen grooves have fifty-four wires each and fifteen loops are protruding. Cut the wire and twist it to the starting end. This will give a sixteenth loop. No cut is to be made during the entire winding up to this point. Trim off all superfluous insulation on the shaft and slip the commutator into position. Remove the cotton covering from the portions of the loops next to the screws in the segments. Insert both wires of one of the loops in the slot in one of the screws; this connection should not be in a direct axial line, but carried to the second segment beyond, in the direction of rotation. See "F", Figure 54. Solder the wires in position. Bring the second loop to the next segment, and so on until all have been connected. The appearance will then be as if the commutator had been given one-eighth of a turn after the wires

had been connected. The object of this advance, or "lead", is to bring the brushes in a more convenient position. Shellac the connecting wires to prevent unravelling of the insulation. Remove the paper from the surface of core so that the ends of the sheet iron teeth will be exposed. If the winding has been carefully done and tightly pressed in place, no binding wires will be needed; but if desired, a place about one-half inch

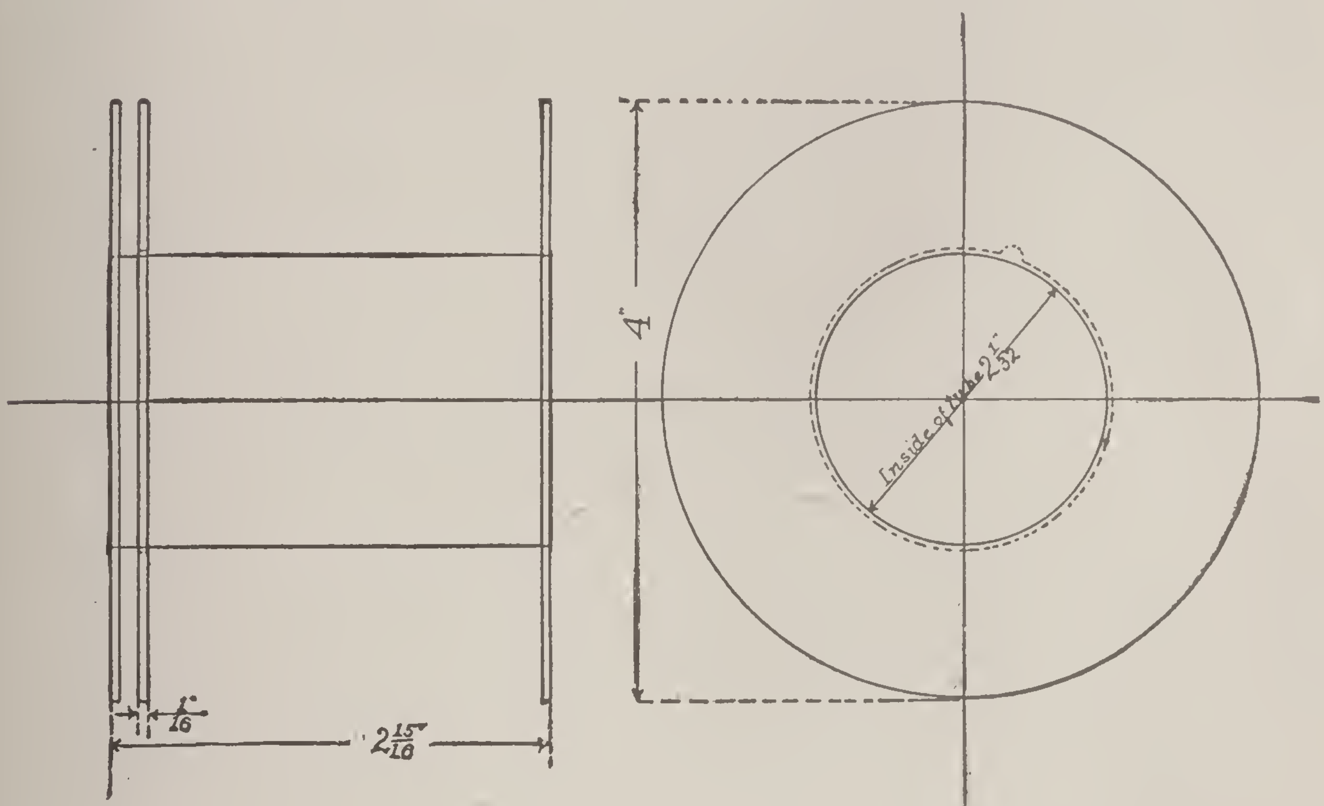


FIGURE 56.

wide may previously have been turned in the center of the core to a diameter of two and fifteen-sixteenths inches; strips of thin mica may be laid over the copper wires for extra insulation, and this space tightly wound with fine brass wire. Solder the wires together before loosening the tension.

It is common practice among manufacturers of dynamos and motors to cover the exposed ends of the armature with conical "dressings" of canvas. The amateur may not feel inclined to bother with this.

Other windings may be:—Seven volts, suitable for plating, can be obtained by using No. 13 (seventy-two one-thousandths inch diameter) wire. Two turns will make one layer, and two layers put in each slot for each half winding, and loops brought out as usual and four turns wound in the next slot. "D" Figure 55

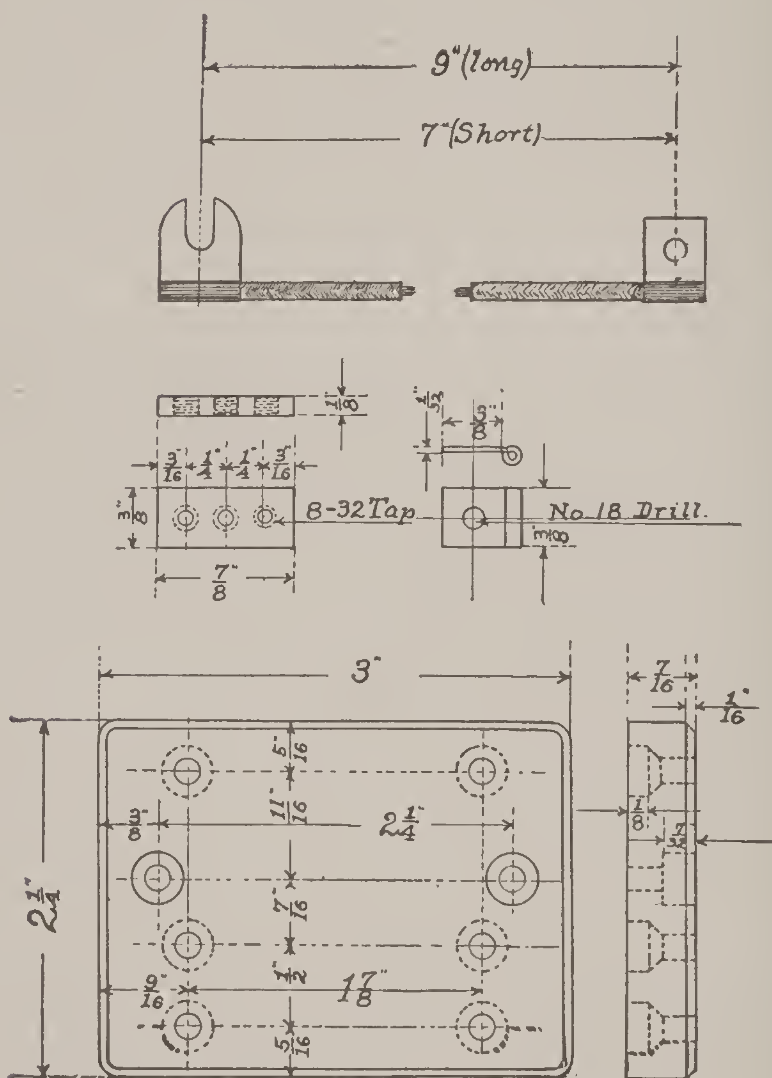


FIGURE 57.

shows the eight wires, the blackened ones representing the four turns of the first half-winding, the light ones showing the wires of the last half. This wire will allow an output of thirty amperes, and copper brushes of extra thickness should be used.

Twenty-five volts. This is a suitable potential for a motor using batteries for a source of current. Use No. 17 wire (forty-five

one-thousandths inch diameter). Put four turns per layer, three layers deep for each half-winding. See "C" Figure 55. It may be necessary to use slightly thinner insulation in the slots in order to get the wire in, but the potential is so low that there would be no danger of "ground" or "short circuit." In crossing the heads, let six wires be on one side of the shaft, and three on the other, in regular order. The halves of the winding will then balance the inequality. This winding will allow a current of eight amperes.

One hundred and ten volts. It is practicable to wind an armature for this potential, but special care and considerable patience will be required. No. 26 wire (sixteen one-thousandths inch diameter) is wanted. Wind six and one-half layers, eight turns per layer for each half winding. "A", Figure 55, shows the arrangement in one slot. There will be 52 turns per segment. The current capacity will be two amperes.

Higher voltage should not be attempted in so small a machine, as the excessive number of turns of wire introduces the insulation so many times as to reduce the amount of copper below its safe current-carrying capacity. An armature would last so short a time as scarcely to repay the builder for his trouble.

Field Winding. In consequence of the round core of the field magnet, this winding can be quickly done in a lathe. Figure 56 shows a detail of a spool. It consists of three leatheroid or fiber discs four inches outside diameter, the two outer ones having a hole two and one-sixteenth inches diameter, the inner one two and one-eighth inches. A tin or other thin sheet metal tube, soldered along its lapped edge, and rolled with a small flange at the ends, holds the discs in position. For winding,

the spool may be slipped on a wooden arbor with check-pieces or flanges to keep the discs from spreading by the crowding action of the wire.

Wind four or five layers of paper around the tin tube, duly shellacked. The edges of the paper can be pressed under the loose disc and lapped onto the others. Put the starting end of the wire through the notch, and draw through a considerable length depending on the size used. Wind one turn of this end length backwards around the spool and coil the rest around the arbor. Press the loose disc against this one turn, and wind two or three layers in the main part of the spool. By hand, wind two or three turns backwards, from the wire on the arbor. Put a piece of thin paper on the main coil and wind several more layers; give the end wire a few more turns and so on until the requisite number is in place. It will be seen that the object of the extra disc and the long protruding end at the start was to keep the wire leading to the first layer well insulated from the successive ones, and also to leave the inside end so that if accidentally broken off, a turn or two can be unwound without disturbing the main part of the spool.

If fine wire is used the ends may finally be led through holes drilled near the edges of the discs, but large wires can be tied to the discs by string taken through a number of small holes. Leave the ends protruding about six inches. As usual with electrical apparatus, shellac the outside layer.

About fifteen hundred ampere turns are required for field excitation; the particular sizes of wire will depend on the voltage of the armature.

Fifty volts. Series: five pounds of No. 13 wire (seventy-two one-thousandths inch diameter) wound eleven layers deep.

Shunt: three pounds of No. 25 wire (eighteen one-thousandths inch diameter) wind thirty-three layers deep. For a compound field use first two and one-fourth pounds of No. 26 wire (sixteen one-thousandths inch in diameter) twenty-nine layers deep; wrap on a few turns of thin paper, shellac discs of paper over the leading ends of the wires to protect their insulation, and wind, in the same direction, one and one-half pounds of No. 14 wire (sixty-four one-thousandths inch in diameter) three layers deep.

Seven volts. A series field is unsuitable for plating. For shunt use four and one-half pounds of No. 17 wire (forty-five one thousandths inch in diameter) seventeen layers deep. A compound winding may have in the shunt, three pounds of No. 18 wire (four one-hundredths inch in diameter) fifteen layers deep, and in the series one and one-half pounds of No. 6 wire (one hundred and sixty-two one-thousandths inch in diameter) one layer deep.

Twenty-five volts. Series: four and one-half pounds of No. 10 wire (one hundred and two one-thousandths inch in diameter) seven layers deep. Shunt: three pounds of No. 22 wire (twenty-five one-thousandths inch in diameter) twenty-three layers deep. Probably the builder would have no occasion for a compound field for this potential.

One hundred and ten volts. Series: four and one-half pounds of No. 17 wire (forty-five one-thousandths inch diameter) seventeen layers deep. It will be noticed that this is identical with the shunt requirements for seven volts. Shunt: three pounds of No. 27 wire (fourteen one-thousandths inch in diameter) forty-one layers deep.

In each case an odd number of layers has been stated in order

to bring the terminals of the coils at opposite ends of the spool.

Connections. Any kind of seasoned hard wood is suit-

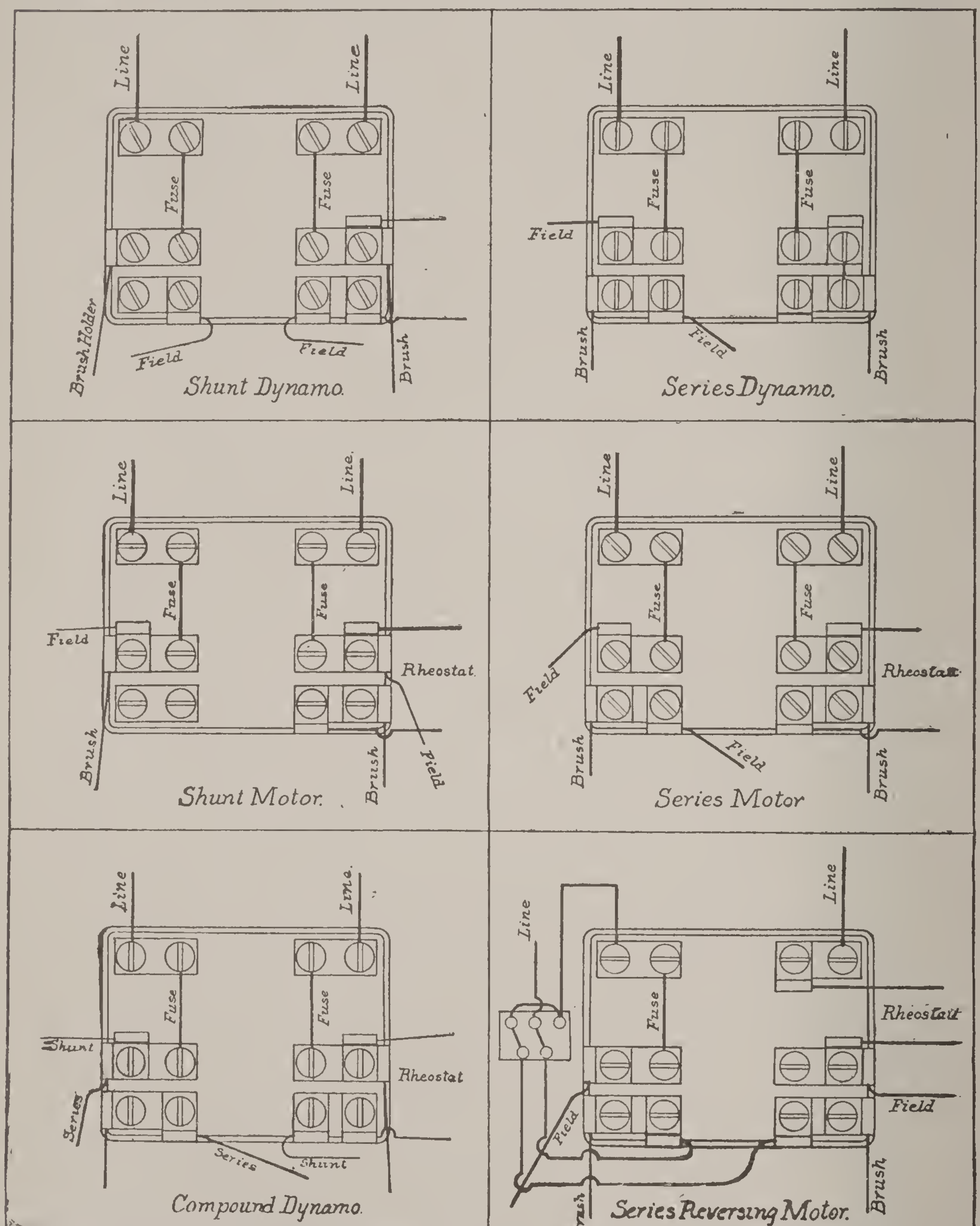


FIGURE 58.

able for the connection board. Finish it in varnish or shellac, and drill as shown in Figure 57. Rectangular brass strips are

to be drilled and tapped 8-32 and attached to the board by screws "f" (Figure 47), inserted through from the back and entering the center holes. The two end screws for each strip "g" (Figure 47) enter the board one-eighth of an inch to prevent "skewing." These holes may be made with a No. 18 drill, after their location has been marked from the strips. Use no shellac on the surface of the brass as electrical contact would thereby be destroyed. Connections are made by soldering sheet copper clips to the wires and clamping them to the blocks. Incandescent lamp cord is suitable for flexible cables to connect the brushes with the terminals. One strand will be sufficient for the current of a fifty or one hundred and ten volt armature, but two strands for the twenty-five volt, and four for the seven volt winding should be used, all soldered into a sufficiently large clip.

By means of this simple arrangement of contact blocks, almost any combination of wires may be made, allowing the machine to be used for a variety of purposes. Figure 58 also shows the necessary wiring for connecting as series, shunt, or compound dynamo; series, shunt, or reversing motor. It is not the purpose of this book to describe switch-board appliances, so locations only of rheostats and reversing switch are shown.

After assembling the machine, the field wires should be straightened, and short pieces of small soft rubber tubing slipped on, so as to insure insulation from the frame.

Testing and Using. The various uses to which the machine is put, and conditions under which it works, will determine just which of the connection board arrangements to adopt.

If used as a dynamo to run incandescent lamps or a plating bath,—the potential controlled by a rheostat in the field,—

use the "Shunt Dynamo" board, or if fairly close automatic regulation is desired, use the "compound" connections. A rheostat in the shunt circuit will still be useful to compensate for variations in speed. When no rheostat is wanted, connect its two points on the board with a short wire.

In starting a shunt or compound dynamo, turn the rheostat until all the resistance is "out," that is equivalent to dispensing with its use. Let the main switch controlling the lamp circuit be "open." Drive the armature at its correct speed, 2600 revolutions per minute. Set the brushes on the "neutral" point,—that is, on segments which connect with coils just half way between the two pole pieces. The correct location is shown in Fig. 44. Let the brushes bear with a firm yet even pressure; lift one of them from the commutator and touch wires leading from a battery, or other source of continuous current, to the field terminals. This is to put some initial magnetism into the iron. Remove the battery wires and replace the brush. Move the yoke slowly back and forth; if current is being generated, sparks will appear at the brushes, and strong magnetism be felt at the poles. For use, keep the brushes on the neutral point, which is the position of least sparking, indeed there may be an entire absence of that evil. If no current is generated, remove the screws holding the cable terminals and exchange their location by connecting the long one where the short one was. The dynamo should now generate. Always allow a few minutes for the machine to "build up," so called. A shunt dynamo is often very sluggish in starting. Now connect the lamps by closing the main switch, turning the rheostat if necessary to adjust the potential. Safety fuses of standard make should be used as shown. In case of overload, or

accidental short-circuit, the fuses melt and save the armature from "burn out."

For starting a compound dynamo,—the same method may be used, with the additional precaution to observe that the current in the series coil must be in the same direction as in the shunt; otherwise its influence would be to oppose instead of help the regulation.

A series dynamo is suitable for running an arc lamp,—in this case a small one,—and for general experimenting. Adjust the brushes and connect a battery to the line terminals. The armature will try to run as a motor; if it tries to turn against its brushes, remove the battery wires, connect the line, and drive the armature in the direction of its brushes; the dynamo should now generate. If, when the battery is connected, the armature turns *with* the brushes (in the direction in which they point), reverse the cables leading from the brush holders. Driven in its proper direction again, the armature should generate.

Three cases as a motor need to be considered. If uniform speed is desired, independent of the load, a shunt field should be used. If current is supplied from a constant potential circuit, a rheostat must be connected in the armature circuit to prevent an over-current. Turning the main switch will allow the fields to get magnetised, but the armature current has to travel through the rheostat. As the speed increases, turn the resistance out. If the armature tries to run in the wrong direction, reverse the brush holder cables. If primary batteries are the source of current, the gradual lowering of the zincs into the acid will obviate the necessity of a starting rheostat.

For variable speeds a series motor is required; a rheostat

will still be necessary for use on constant potential mains. A series motor will always run at a constant speed if the load is constant; hence it is common to put series windings on fan motors because of cheapness. If used to drive a fan a collar should be put on the pulley end of the shaft to run against the lining and receive the "end thrust," the regular shoulders being insufficient for so much pressure.

Besides the ability to run at various speeds, a "reversible" motor is sometimes desired. One line wire (Fig. 58) leads to the connection board, the other to the reversing switch, which is shown in diagram. The circuits are such that the fields are always magnetised with the same polarity, but the direction of the current through the armature is reversible by moving the two parallel fingers of the switch. The reversal of a motor is accomplished by changing the current through either field or armature,—not through both. A starting rheostat is also included in circuit; one of the fuses is omitted in order to make the connections more convenient.

Regular sizes of fuses should be,—for the one hundred and ten volt winding, three amperes; this is the smallest size made. For fifty volts, four amperes; for twenty-five volts, eight amperes; and for seven volts, thirty amperes capacity.

If the builder has followed the directions carefully the machine will work to perfection,—it cannot help it. This dynamo is suitable for a variety of practical uses, not the least of which may be as "exciter" for the fields of a small alternator. As a motor, it will run a fan, several sewing machines, or small lathe. With success assured from the small outlay thus required the builder may properly attempt the construction of larger machines.

CHAPTER IX.

HOW TO BUILD A TWO-LIGHT DYNAMO.

ON the following pages are given complete directions for making a small dynamo and motor for experimental and laboratory use; a machine that is not a toy, but capable of affording continual interest and profitable research, and will be prized by any one of mechanical inclination.

So many and curious are the applications of electricity that to realize their utility and significance, even faintly, is possible only by personal experiment and repetition. A set of chemical batteries can be called upon to supply a current of electricity, but such paraphernalia is inconvenient and expensive. Besides, the modern, and only practical method of generating the current, is by dynamos.

Motors, much like dynamos in construction, run our workshops and railways. The young candidate for electrical qualifications may consider that he has passed excellent preliminary examinations if he constructs and owns a practical dynamo.

Figures 59 and 60 in this article show a dynamo (or motor) of simplest design, but a marvel of adaptability. The frame, comprising the field magnets and supports for the armature bearings, is in but two pieces. The armature is made of one piece of iron, with one coil of wire. Yet this small

machine will require one-man power to drive it to its full capacity, and will make a very energetic motor. It will generate a current, whether turned in one direction or the other. As a motor it can be made to run at will in either direction. Furth-

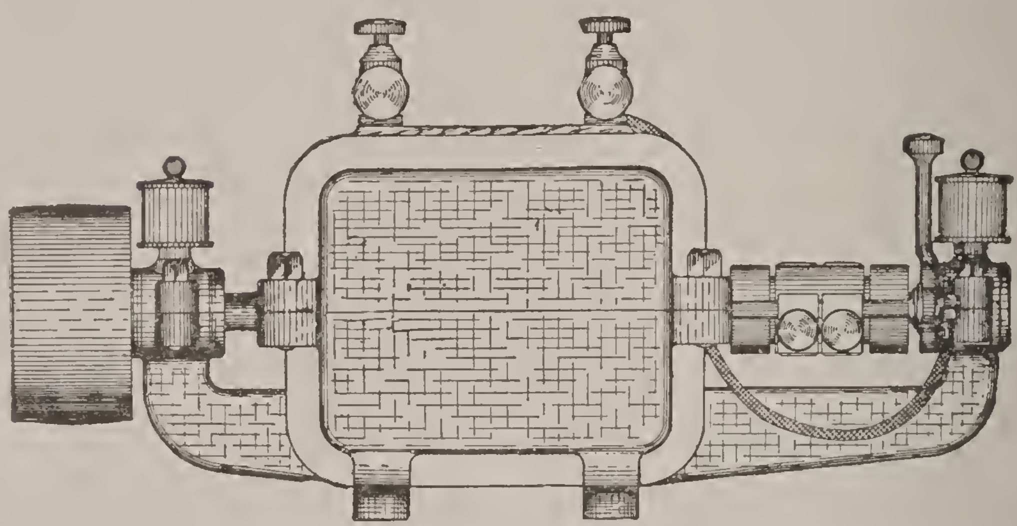


FIGURE 59.

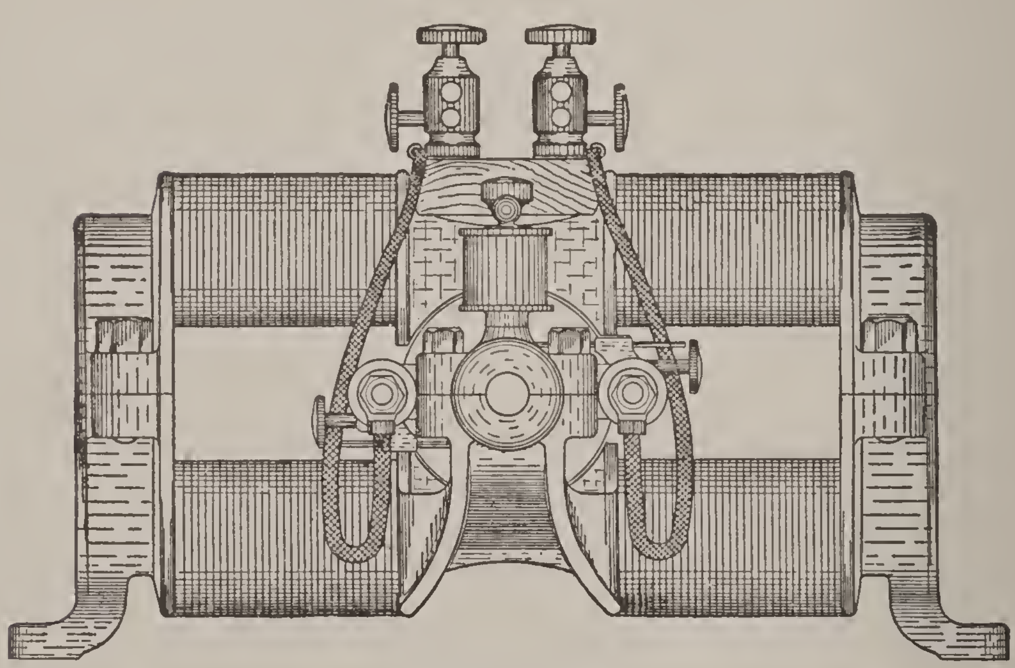


FIGURE 60.

ermore, it is capable of doing what seems impossible—it can furnish a current in a continuous or alternating direction. No laboratory or electrical cabinet is complete without some means of getting an alternating current. For a continuous current the

brushes rest on the commutator, as shown in the cut. In this case it is self-exciting; that is, the dynamo is complete in itself and magnetizes its own fields. By running one brush on each of the rings, shown on each side of the commutator, and "separately exciting" the fields from some other source, an alternating current is available. By another arrangement of internal connections the commutator and collector can be capable of making a "self-exciting, alternating current dynamo." Such a combination is not attempted by any machine now on the market.

By winding proper sizes of wire on the armature and field cores, any strength, or "potential," of current can be obtained. For ordinary uses a current of 25 volts will be found convenient. No. 18 wire on the armature, and No. 14 on the fields would do this.

At this potential eight amperes could be secured. A higher potential, but less current would result from use of fine wire, or a lower potential and more current with larger wire.

The working drawings with dimensions show the construction so clearly that a detailed description is almost superfluous. Making the patterns is tedious, and perhaps inconvenient, and with foundries distant, it may be impossible for each one working independently to avail himself of this article. By clubbing together, only one set of patterns would be needed, and castings obtained at low rates.

The upper and lower parts *a* and *b* of the frame, the caps for the bearings and the pulley, are of common cast-iron; the armature of annealed cast-iron. The rest of the metal parts except the shaft, are of brass.

In making this machine, the four legs are first to be filed

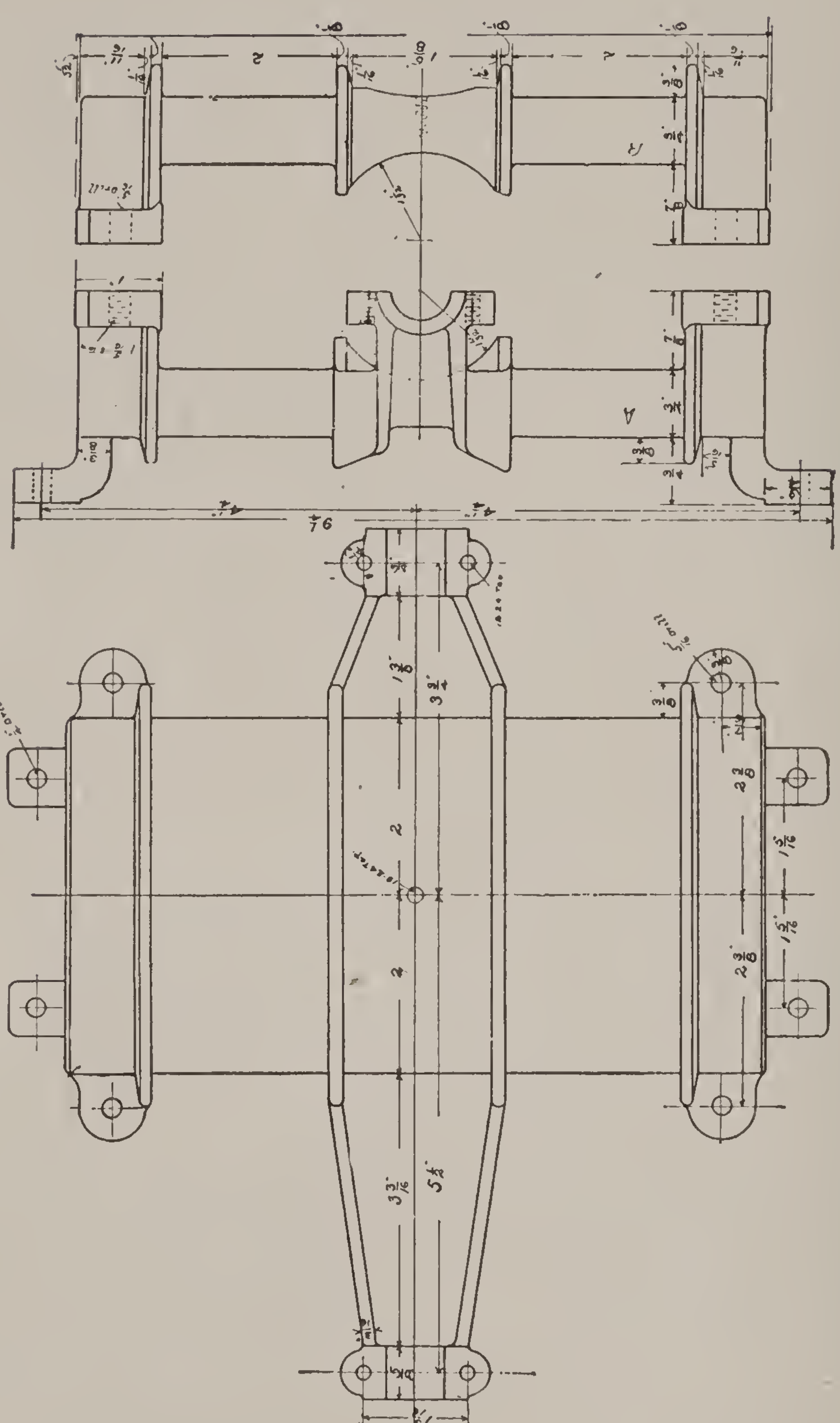


FIGURE 61.

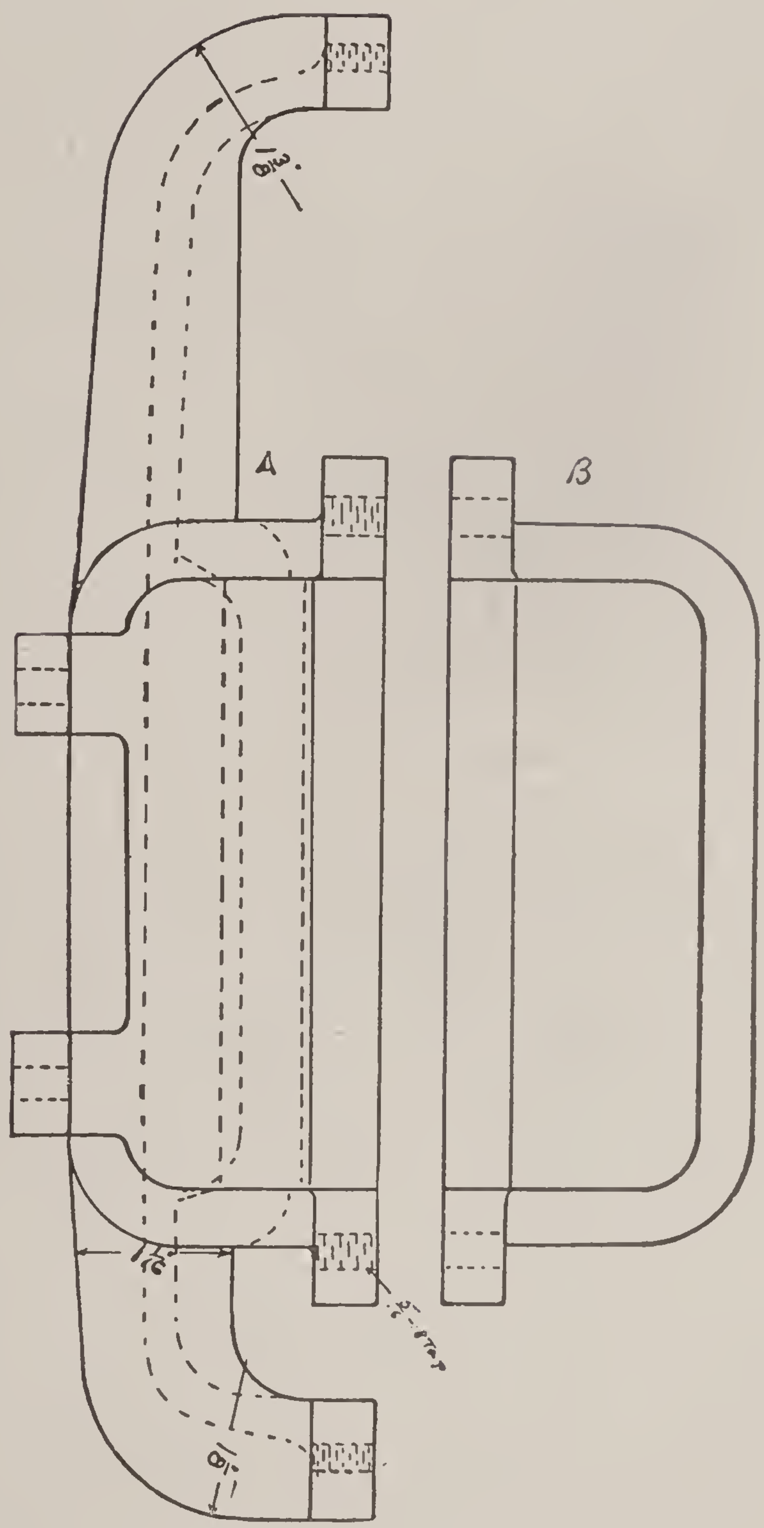


FIGURE 62.

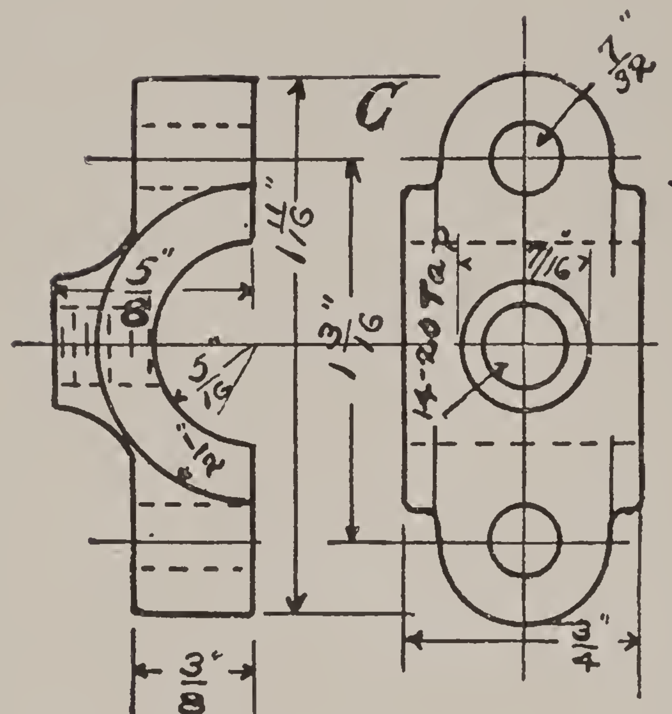


FIGURE 63.

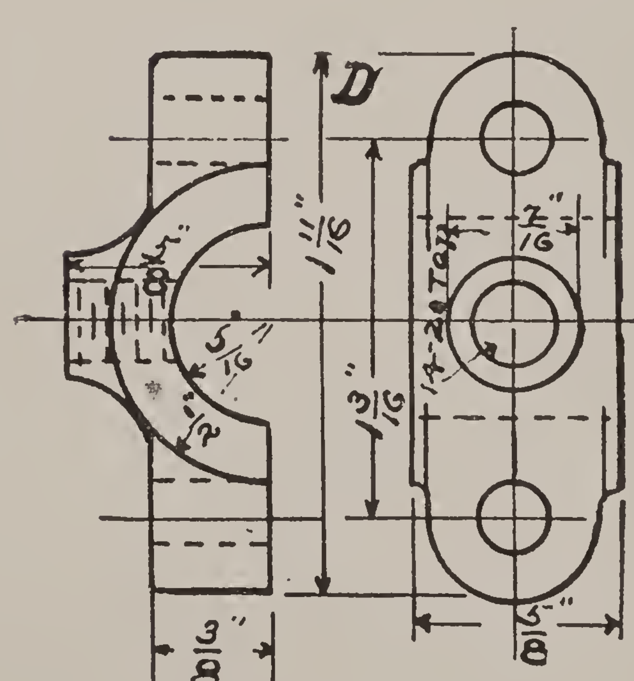


FIGURE 64.

or planed flat, to secure a firm rest on the planer. For the next step, plane the parts where the halves of the fields bolt together, and where caps screw on. The holes may then be drilled, tapped, and screws inserted. After the caps *c* and *d* are tightly screwed in place, the builder may proceed to bore out the $\frac{5}{8}$ inch holes where the bearings of the armature shaft are to rest. This can best be done with a boring bar in a lathe.

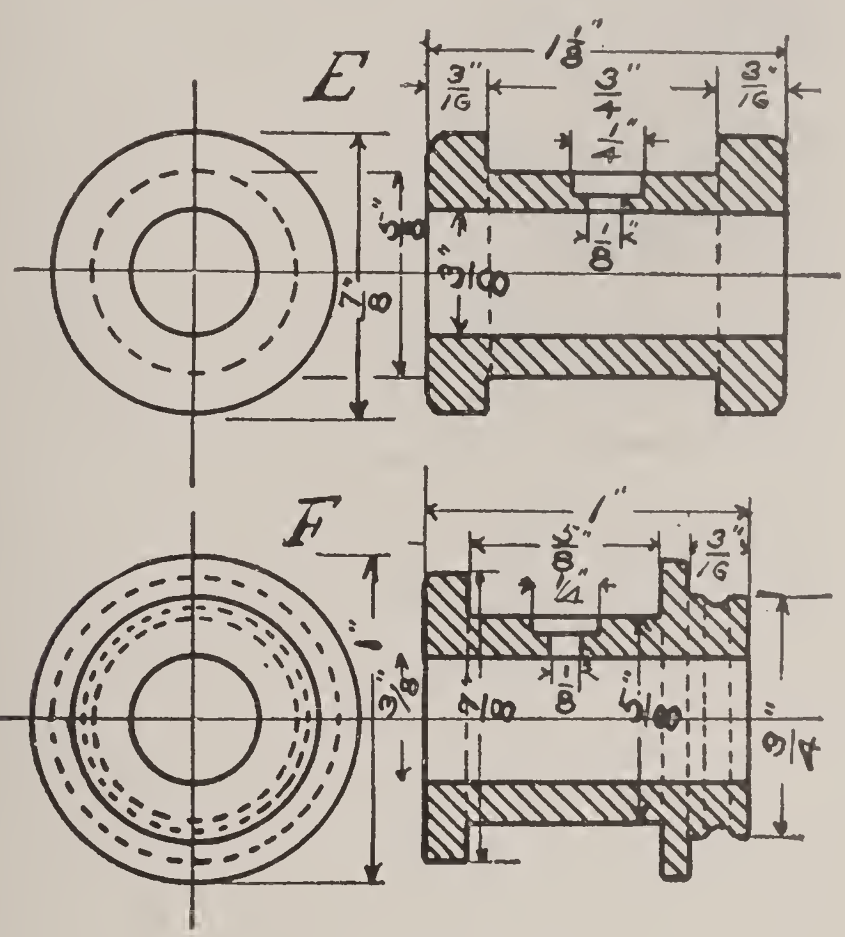


FIGURE 65.

Or these may be drilled between lathe centers, if the holes are afterwards reamed together to insure exactness. The outside and inside rims should be faced smooth that the linings may fit nicely.

To bore out the fields is usually troublesome; but in this machine the boring is easily accomplished. After the arms are

finished, as first directed, a boring bar $\frac{5}{8}$ inch in diameter, with a cutter head in the center can be laid in place, using the arms as supports. The boring to size can then be done in any screw cutting lathe.

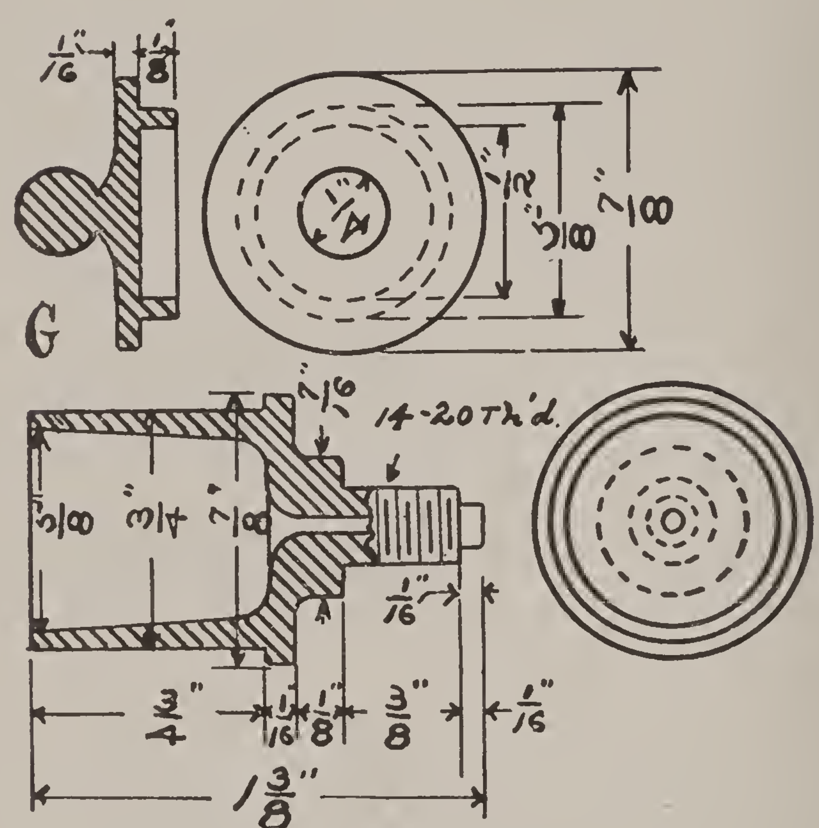


FIGURE 66.

Hard brass or gun metal is suitable for the bearings or lining *e* and *f*. These are to be made in one piece each, instead of in halves. They are thus easily made, and cheaply replaced when worn out. The oil cups *g* enter the small hole in the top and prevent the linings from turning.

The armature casting *h* should be annealed by heating to a bright red, and then cooled slowly for several hours. Drill the $\frac{7}{16}$ inch hole through the center and drive it upon a short arbor for turning. The outside diameter is to be just 2 inches. As the field bore is $2\frac{1}{16}$ inches, there will be, when the armature is in place, $\frac{1}{32}$ inch clearance. Turn the shaft *i* to its specified dimensions

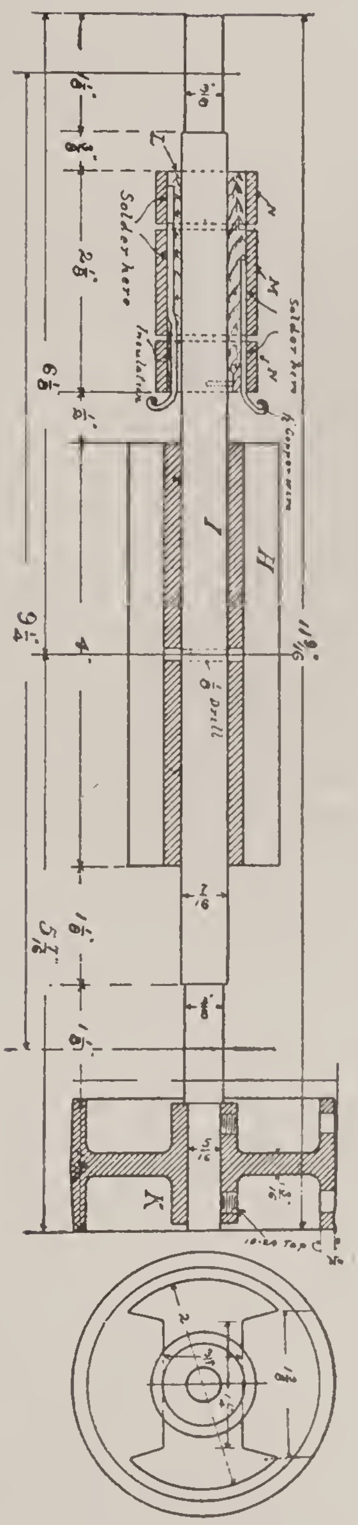


FIGURE 67.

and drive the armature tightly on the center portion; a few $\frac{1}{8}$ inch steel pins will insure non-loosening. The pulley *k* is to be fitted to the 5-16 inch end of the shaft and held in place by two set-screws butting on flattened spots.

As it is difficult to work copper, brass can be used for the commutator and collector. Boxwood or hard rubber will make a good hub. The commutator or center portions *m* should be first made. Fit the tube tightly to the center, and put in the small screws; then remove the tube and saw it in halves. Groove the wood for the connecting wires and fit on the two collector rings *n*. Again remove the brass tubes and solder the connecting wires in place. One wire is to connect with the inside ring and one commutator segment; the other wire with the outside ring and opposite segment. A small pin should be put in the shaft to keep the commutator from slipping. Make the position of the division between the commutator segments as shown in the figure.

Fit the yoke *o* to the inside rim of the short lining and tap the hole for the set-screw *p*. Studs or spindles *q* for the brush holders, enter the ends of the yoke suitably insulated with hard rubber washers and bushings *r* and *s*. Three pieces only are used to form the brush holder,—an outside part *t*, and inside part *u*, and the screw *v*. When the screw is tightened the brush *w* (of leaf copper), and stud *g* is tightly clamped. The brass ears *x* into which the flexible cables are soldered, are opened to the center hole to allow easy removal.

A maple connection board *y* surmounts the machine. One screw in the center is sufficient to hold it. The brush holder cables end at two of the binding posts, the field wires at the other two.

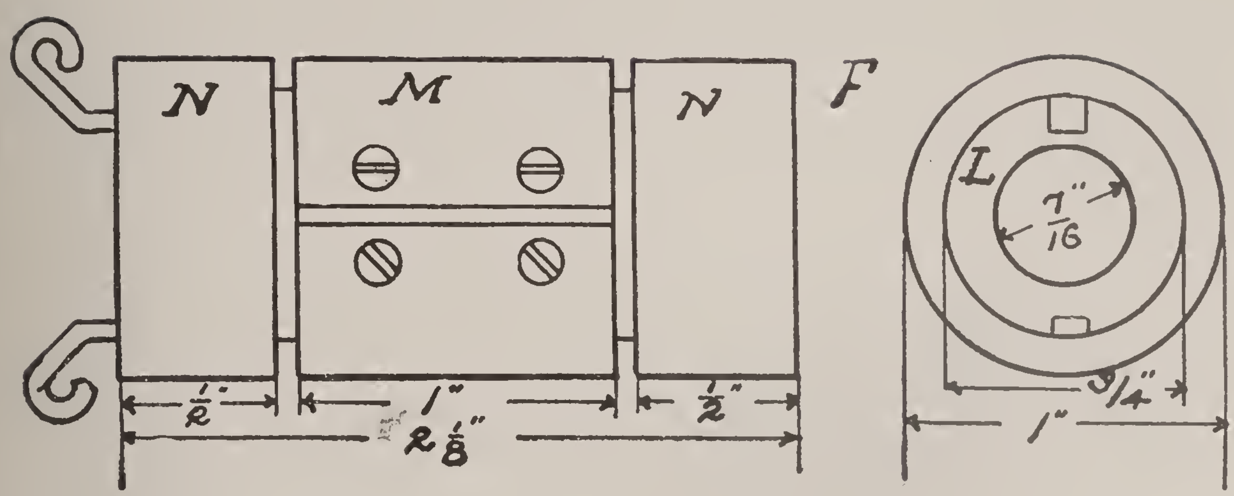


FIGURE 68.

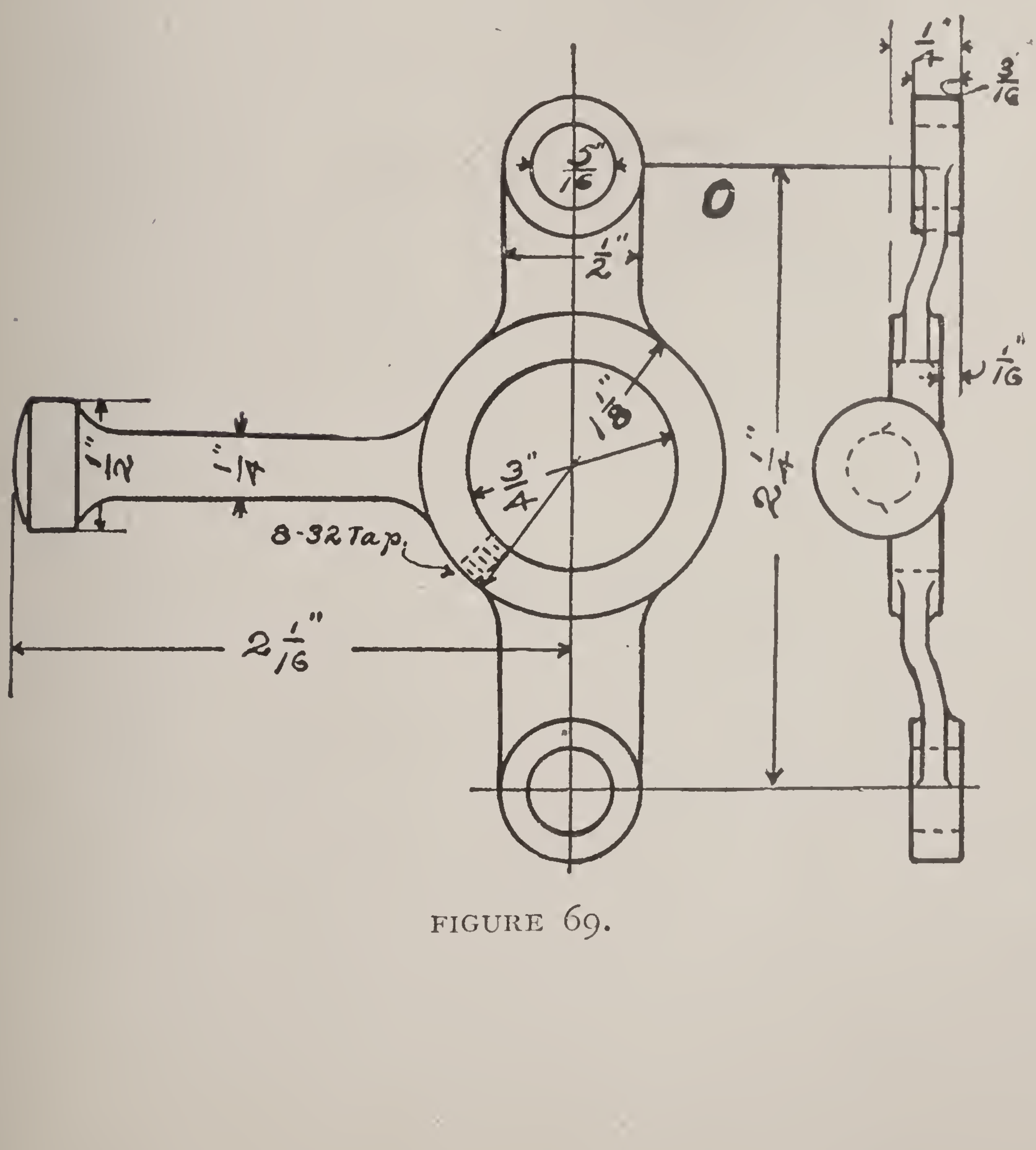


FIGURE 69.

The builder is now ready to wind on the wire. File off any roughness on the iron, and insulate with several layers of manilla paper well shellacked. The armature is to be wound

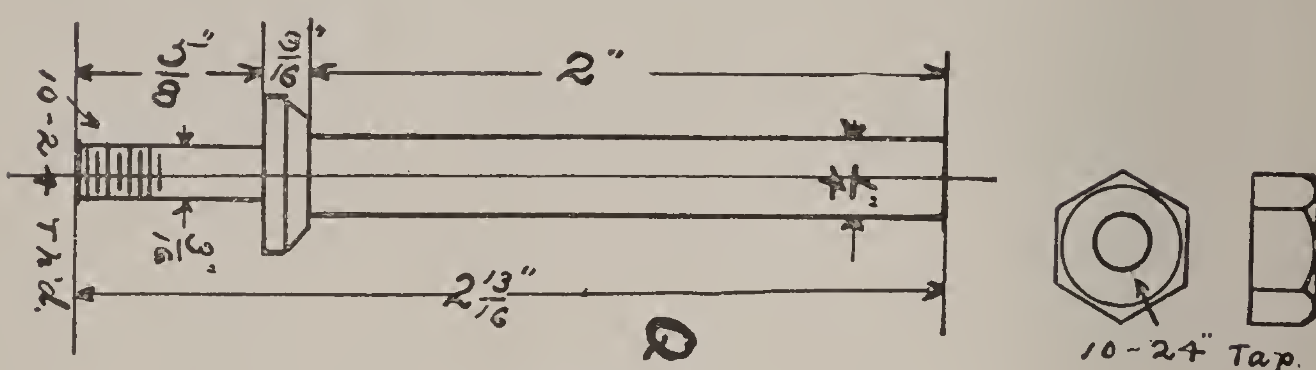


FIGURE 70.

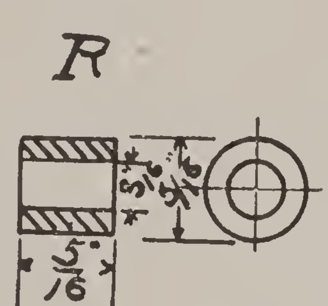


FIGURE 71.

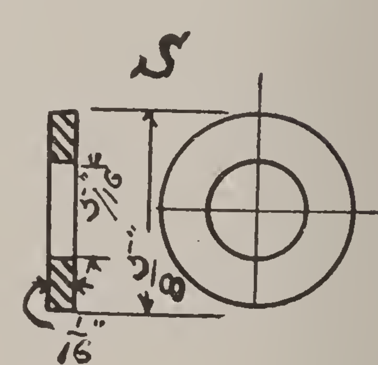


FIGURE 72.

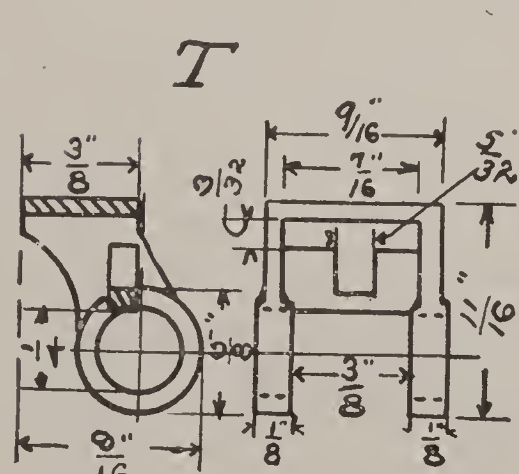


FIGURE 73.

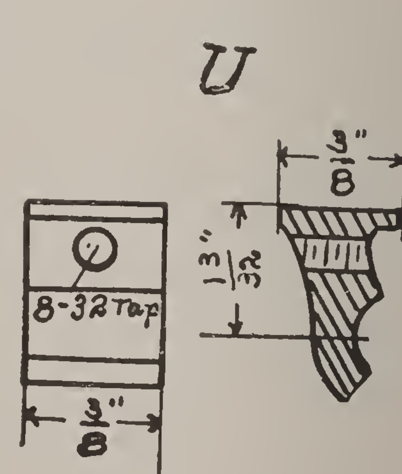


FIGURE 74.

like a shuttle until filled, with No. 18 double cotton covered magnet wire; about $1\frac{1}{2}$ pounds will be required. The four sections of the field will take, in all, eight pounds of No.

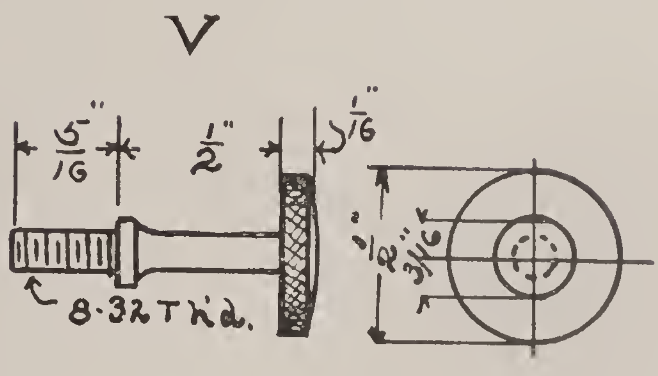


FIGURE 75.

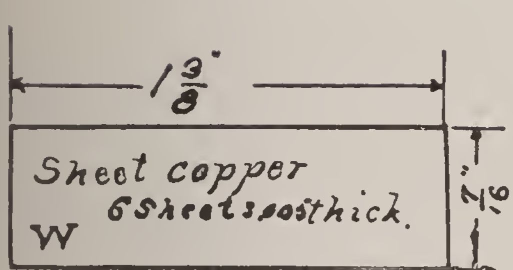


FIGURE 76.

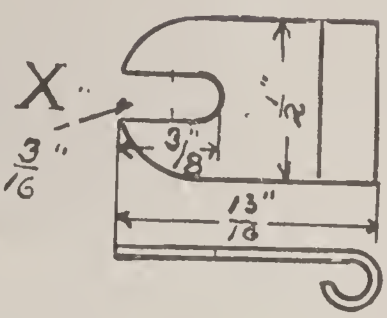


FIGURE 77.

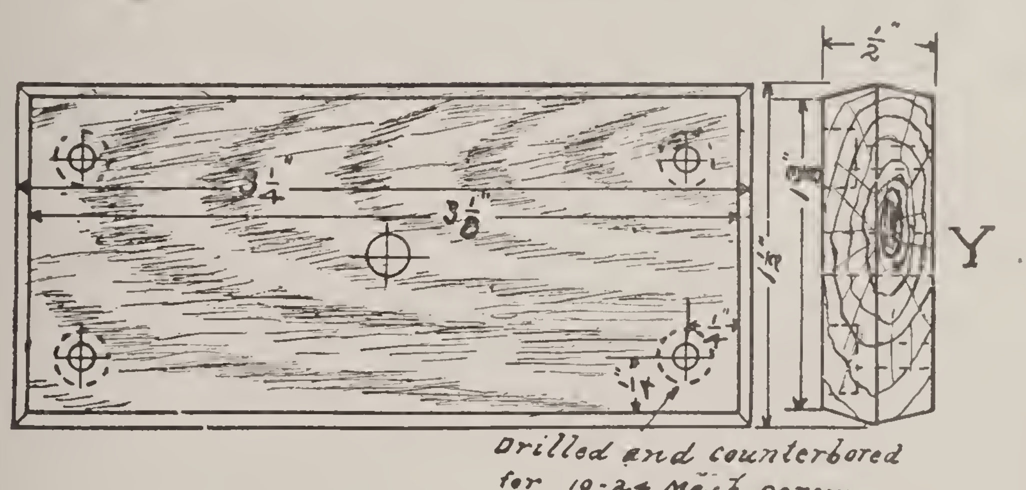


FIGURE 78.

14 wire. Each section is to be wound in the opposite direction from its neighbors, in order to make consequent poles around the armature.

Fig. 79 represents a diagram of the winding. When used as an ordinary series machine the line wires enter 1 and 3, or 2 and 4, the other two being connected with a short wire. The diameter in which the dynamo runs is determined by these connections. The same holds true when used as a motor. If

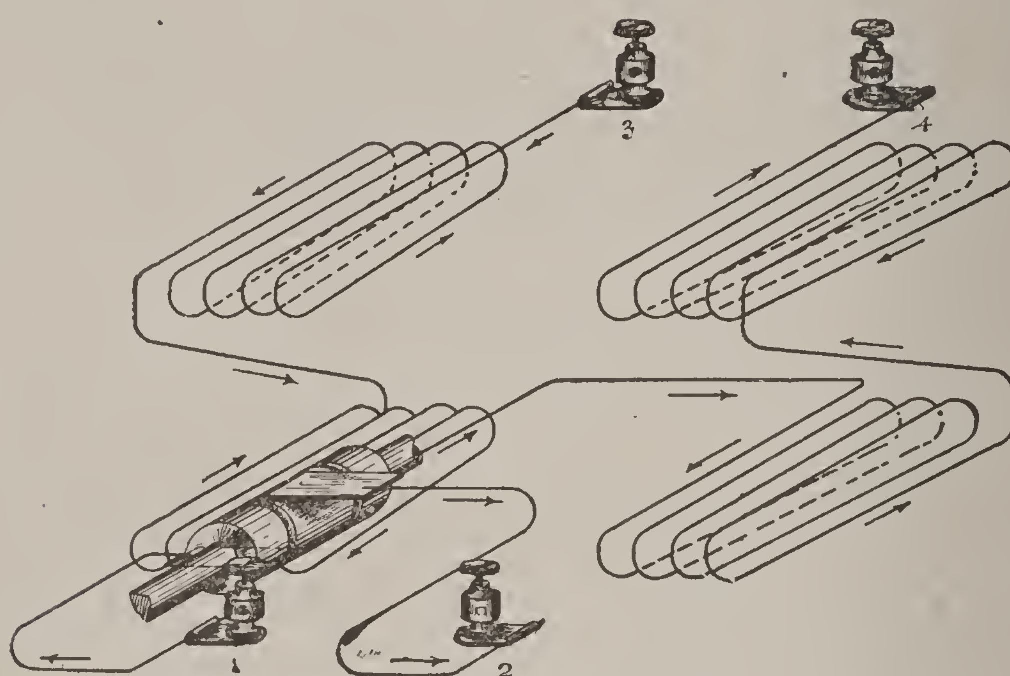


FIGURE 79.

an alternating current is desired, the line is supplied from 1 and 2, while a separate current must be supplied to 3 and 4 to magnetize the fields. Only two brushes are to be used, one on each collector ring.

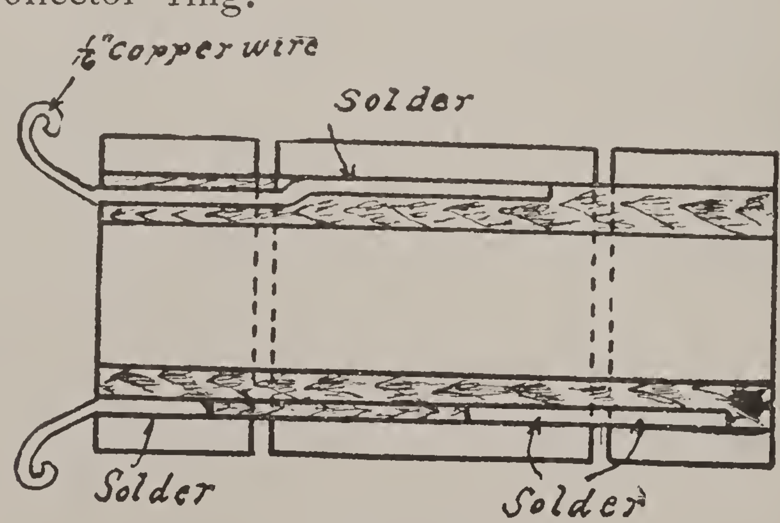


FIGURE 80.

In case a self-exciting alternating current dynamo is built a specially connected commutator-collector and yoke are used.

Fig. 81 clearly shows the connections. Six brushes are necessary. The alternating current generated in the armature first passes to one of the commutator segments, then from one set of brushes, in a continuous direction through the field winding back to the other set of brushes. By contact of these brushes alternately with one segment, then the other, the current is directed alternately again into the outside collector ring, through the line wire, back to the other ring, and the circuit is completed.

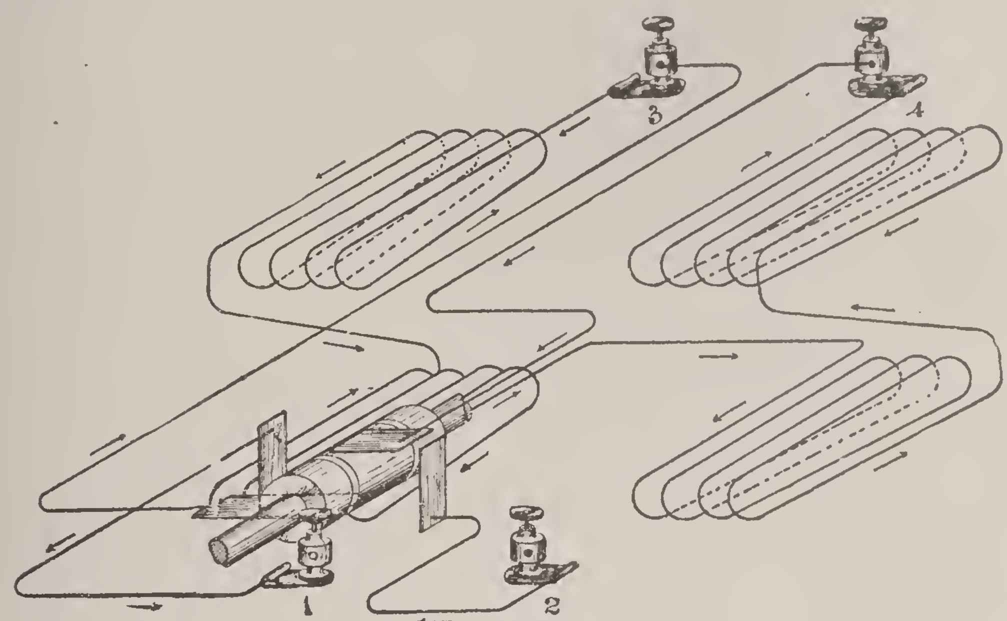


FIGURE 81.

Other forms of armatures can be designed for use in these fields, a drum, or even a ring armature with many segments in the commutator. The field winding may be made shunt, especially for running incandescent lamps. Even a compound field is possible.

For continued use, this dynamo would be driven from a line of shafting; but for experiments of a few minutes' duration hand or foot power is admissable.

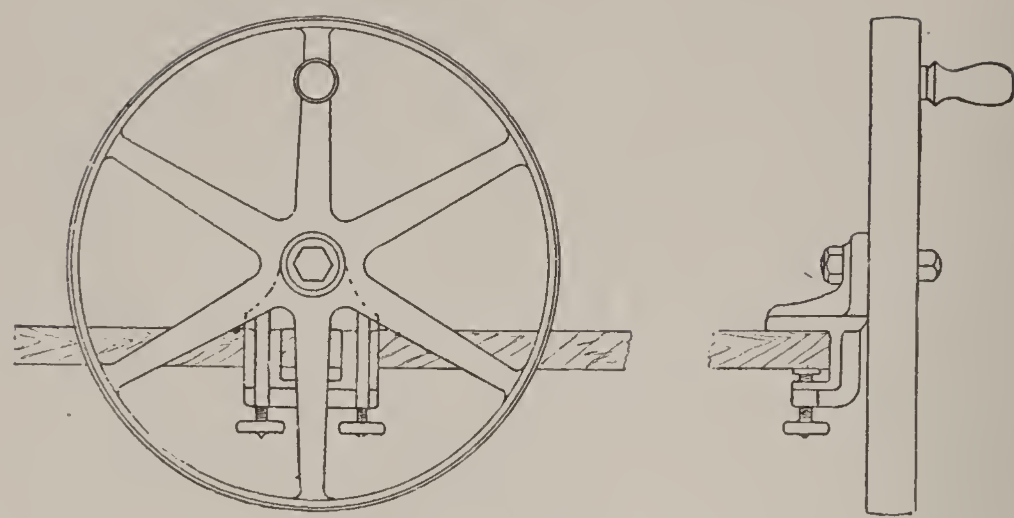
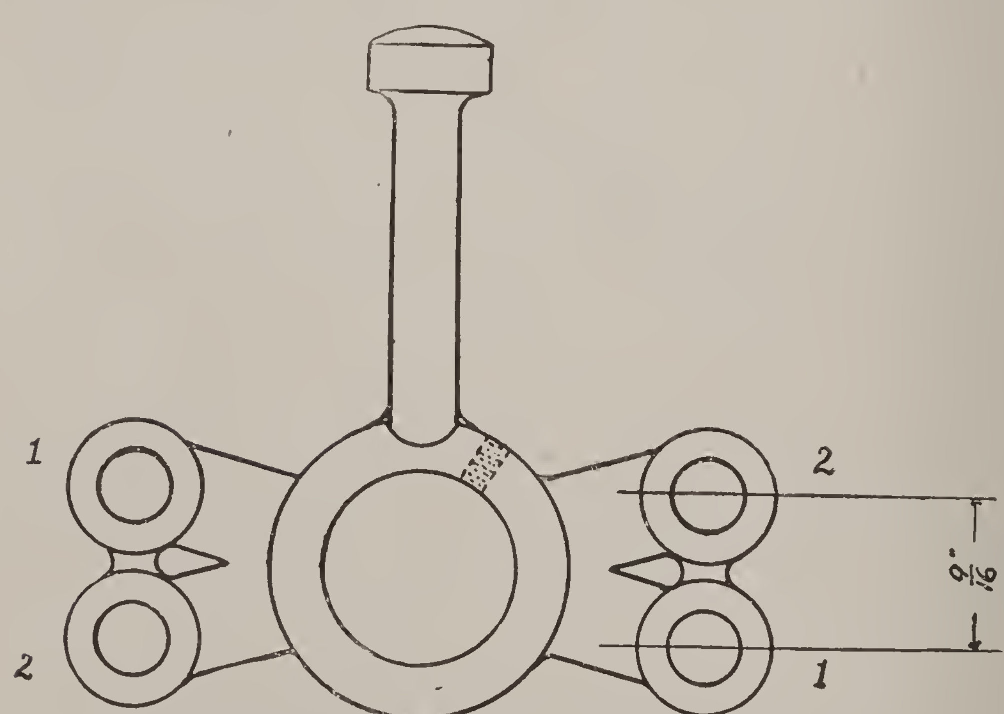


FIGURE 82.

Fig. 82 represents a simple contrivance for driving by hand. A cast-iron frame, light but well ribbed, is secured to a board or table a few feet from the dynamo by two thumb screws. A wheel 15 inches in diameter, $1\frac{1}{2}$ inche face, driven by a handle on one of the spokes, will get up sufficient speed to run t 16-candle power incandescent lamps, or to run a small arc lamp.



Yoke for Self Exciting Alternator –

Nos. 1 and 1 are for commutator brushes

" 2 " 2 " " Collector "

FIGURE 83.

CHAPTER X.

HOW TO BUILD A ONE-HALF HORSE POWER DYNAMO OR MOTOR.

ALL the elements of superiority cannot be found in any one machine. Preference for one point of excellence must be asserted at the expense of some other. In the machine here described, there have been held of decisive importance, light weight, compactness, simplicity, and cheapness. As high a degree of efficiency is not attainable in small dynamos as in those of fifty or one hundred horse power, but when the entire output is below one horse power, the variation of a few per cent. in waste is negligible. Low first cost is here regarded as of prime importance, with a working efficiency between 75 and 85 per cent.

The well known "Manchester" type of field has been selected, together with a Gramme ring armature. In detail of mechanical construction some originalities are introduced, with the aim of making it a modern machine. Complete, it will weigh about 80 pounds.

Figs. 84 and 85 show the end and side elevations of the dynamo as equipped with a compound field, and adapted to running incandescent lamps. Sufficient dimensions are shown in the detailed parts, and such explicit information given as to en-

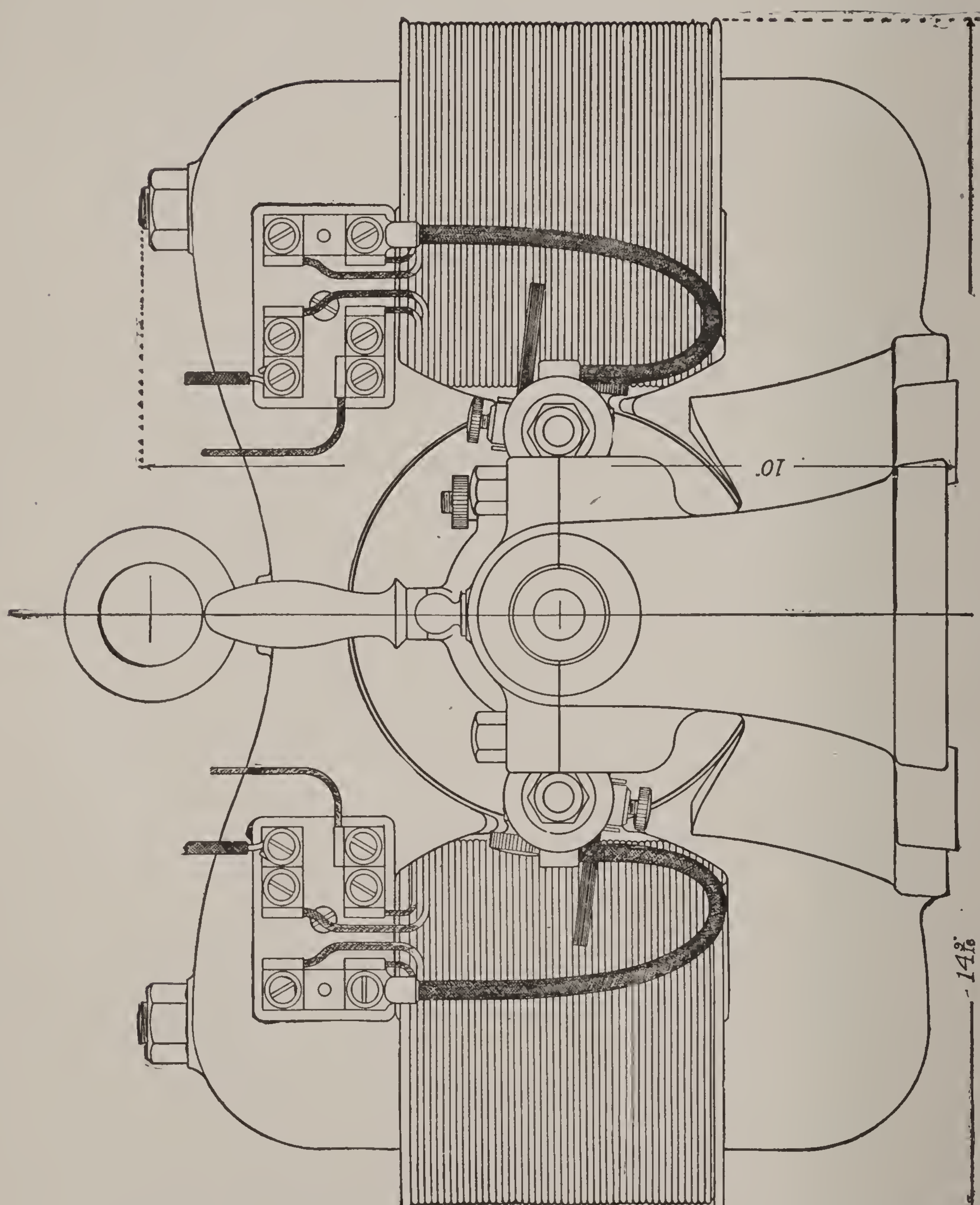


FIGURE 84.

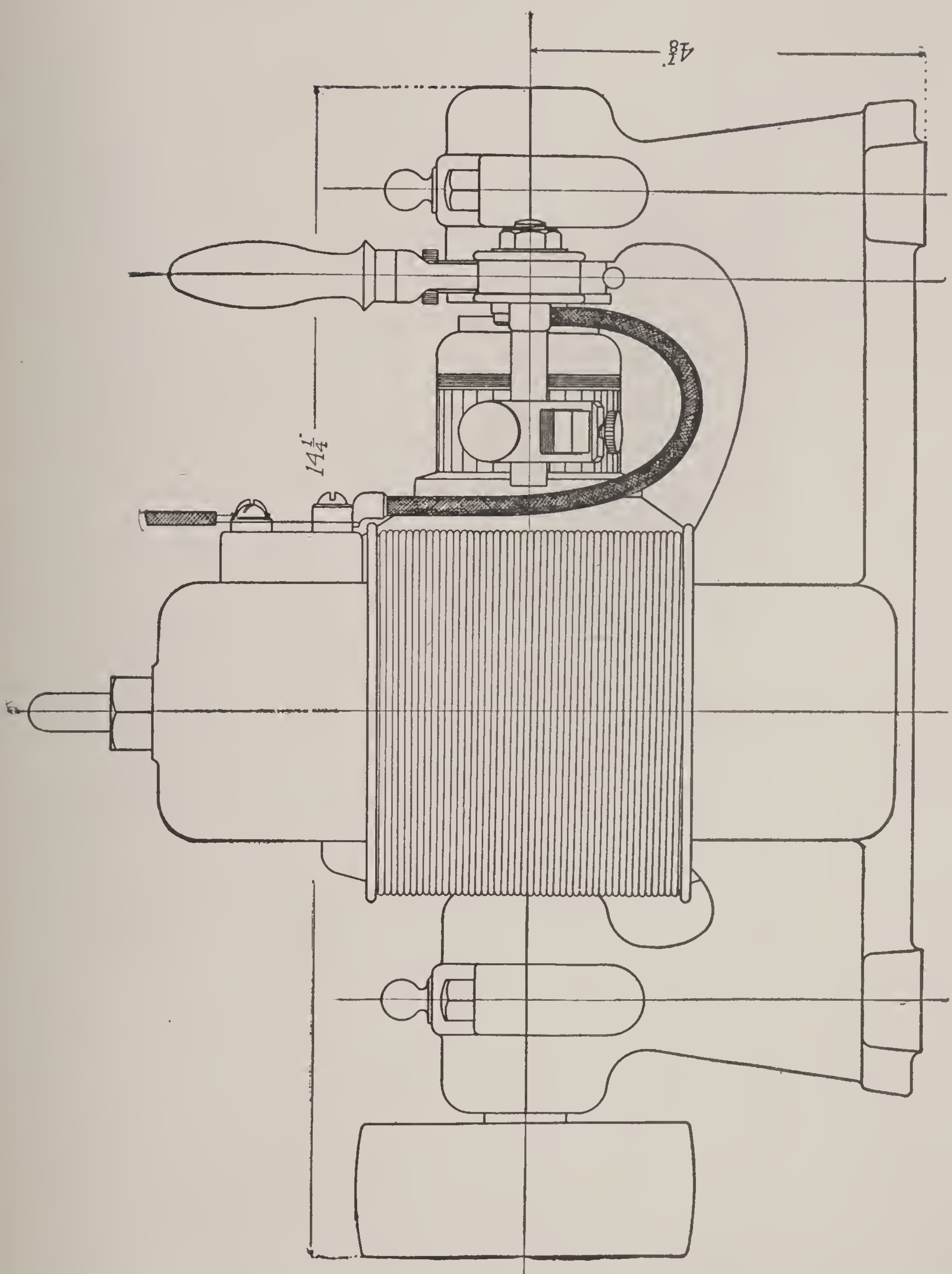


FIGURE 85.

able a person inexperienced in electrical matters to make a successful machine.

Field Magnet and Frame. Referring to the elevations in Fig. 86 and the plan Fig. 87, it will be seen that the lower half of the structure comprises one pole-piece, the base, and the two standards with their caps. Two wrought iron cores occupy the middle position, and the upper pole piece surmounts them.

Very soft cast iron should be used for the pole pieces. Provided with suitable castings, the four spots on the bottom should first be planed; then stand the base right side up and plane the surfaces on which the cores rest, and tops of the standards where the caps bolt on. Plane the joints on upper pole piece also. Plane the caps and screw them in place by means of $1\frac{1}{2}$inches–$\frac{3}{8}$inch–16 hexagon cap screws. Drill the $\frac{1}{2}$ inch holes in the pole pieces for the long bolts that hold the field together. Their location should first be accurately marked, so as to be in line with each other, and the bolts should fit well in order that both halves of the field bore should always be concentric with each other.

Soft wrought iron is to be used for the field cores; what is commonly called cold rolled steel is so close to wrought iron that it is equally suitable. Drill out the $\frac{1}{2}$ inch holes, and drive an arbor in, and turn each to $2\frac{1}{4}$ inches in diameter, and 4 inches long. Square the ends carefully and see that both are as near the same length as it is possible to make them.

Bolt the lower field to the traveling carriage of a lathe and with a suitable bar between centers, bore out the $1\frac{1}{8}$ inch holes in the arms for the bearings. The spaces where the cut is taken are short, as the cored oil wells and grooves occupy

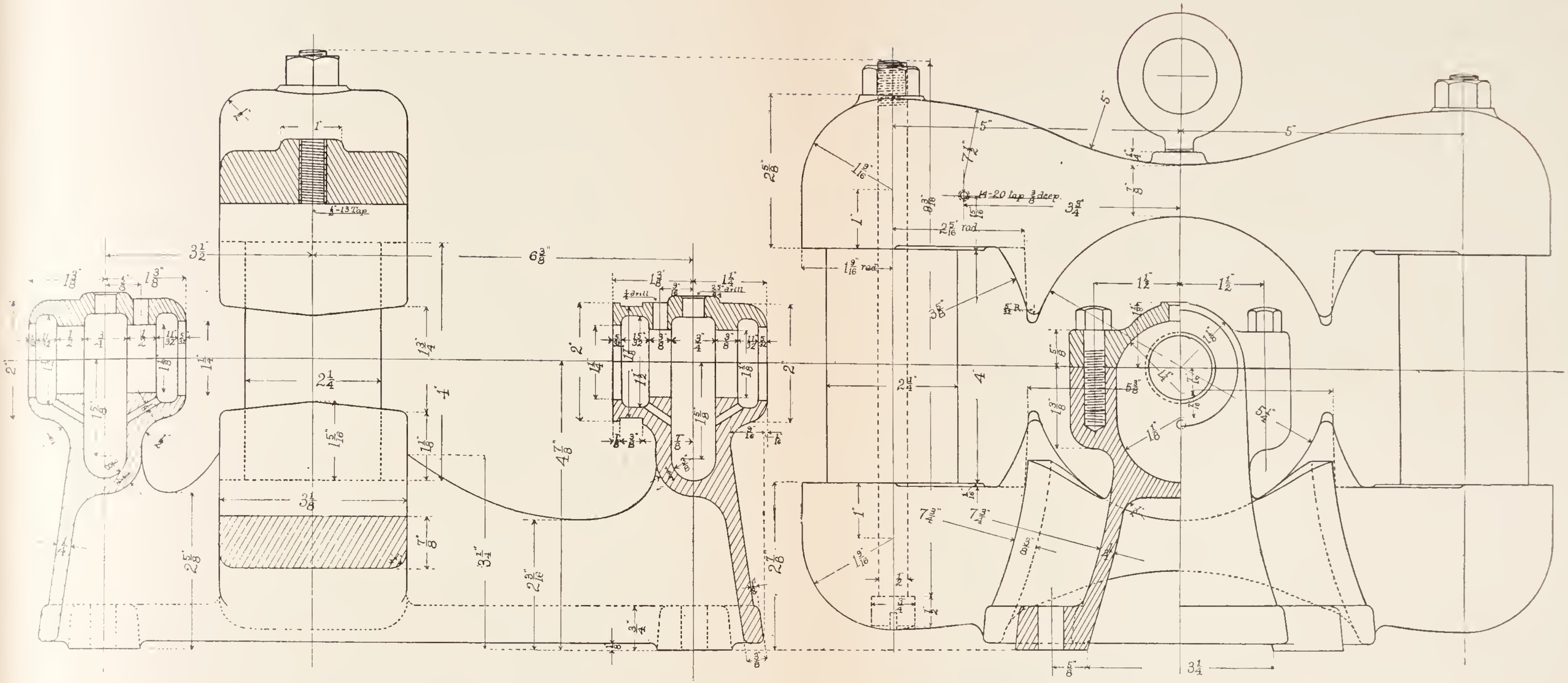


FIGURE 86.

(Opposite page 116.)

the rest of the space. Assemble the frame, and lay a $1\frac{1}{8}$ inch boring bar in the holes just finished; suspend the machine between lathe centers and bore out the field space to $5\frac{1}{4}$ inches in diameter. Feed for the cut may be secured by attaching

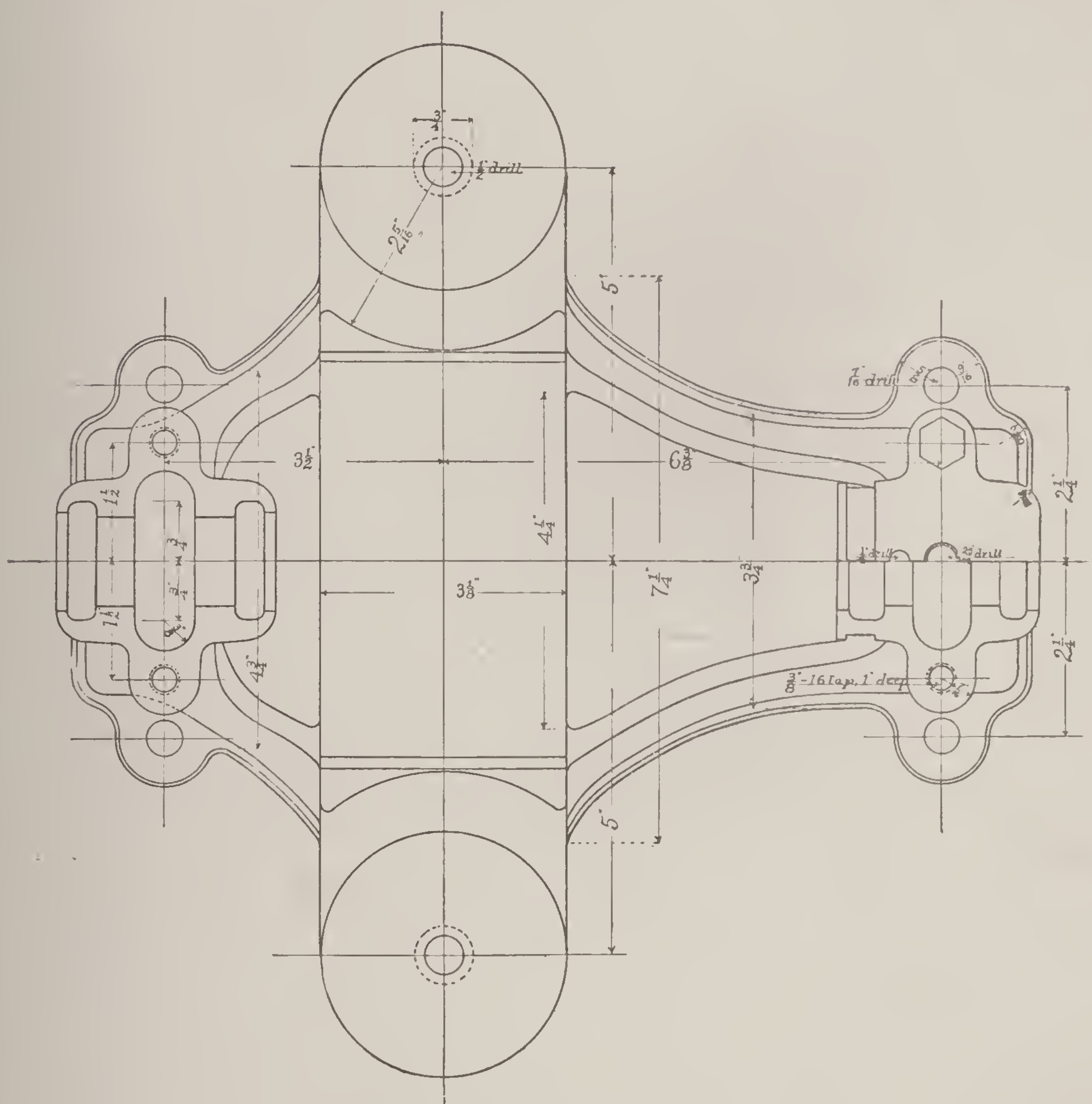


FIGURE 87.

one corner of the field to the traveling carriage. Insert an L shaped tool through a hole in the boring bar and turn the groove in the commutator-end pedestal and cap for the yoke bearing. Remove from the lathe, drill the holes in the feet

and caps. The small holes that lead from the grooves into the oil wells may be best attempted with a breast drill. Tap the holes in the upper field for the eye bolt and the connection board. Chip out any irregularities that may be in the recesses into which the spools extend. If the builder wishes he may tap out holes in the sides of the pedestals for small pet cocks, to drain out the oil when desired.

Armature, Shaft, and Pulley. See Fig. 88. A good quality of machinery steel can be used for the shaft, but 1 inch cold rolled steel will answer. Turn one portion to $\frac{7}{8}$ inch in diameter as far as the shoulder that is left full size; then turn to $\frac{3}{4}$ inch in diameter as far as shown; cut the threads, and fit a hexagon nut; then turn to the other specified dimensions, leaving the $\frac{5}{8}$ inch portions a trifle large for final fitting to the bearings. In cutting the $\frac{1}{8}$ x $\frac{1}{16}$ inch keyways, a milling cutter is preferable to a planer, as there is not the same danger of springing the shaft.

The spiders, Fig. 89, are of gun metal, or tough brass. Chuck, or bolt them to a face plate and bore out the holes in the hubs. Drive them on an arbor and turn off the rims and the arms to the sizes shown. In taking the chip across the latter some care will be needed as the arms are slender; a greater thickness would interfere with the winding space. Turn their ends so as to measure $1\frac{9}{16}$ inches from the flanges. Cut the keyways exactly opposite spokes, and mount the spiders on an arbor back to back, with a key inserted. Cut the 32 slots in a milling machine or gear cutter, if possible, but a careful mechanic will be able to make a hack-saw answer, after carefully marking the locations.

Plain ring punchings of sheet iron are to be used for the

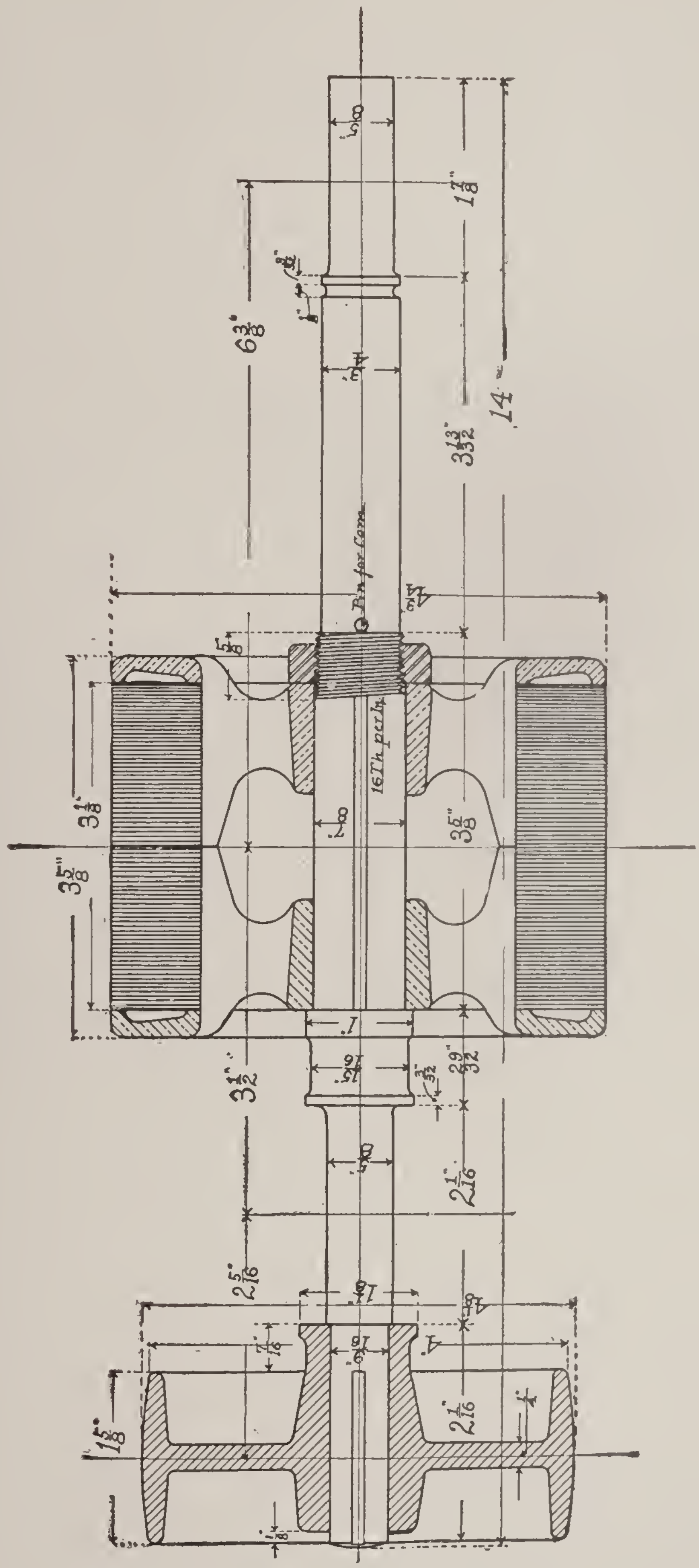


FIGURE 88.

armature core; they are to be $4\frac{3}{4}$ inches outside and 3 inches inside diameter, should slip easily over the arms of the spider, but not be loose. One of the spiders may well be a tight fit on the shaft; lay in the key, and force this spider up to the shoulder. Stand the shaft in a vertical position and slip on as many punchings as the spider will hold. Paper between the

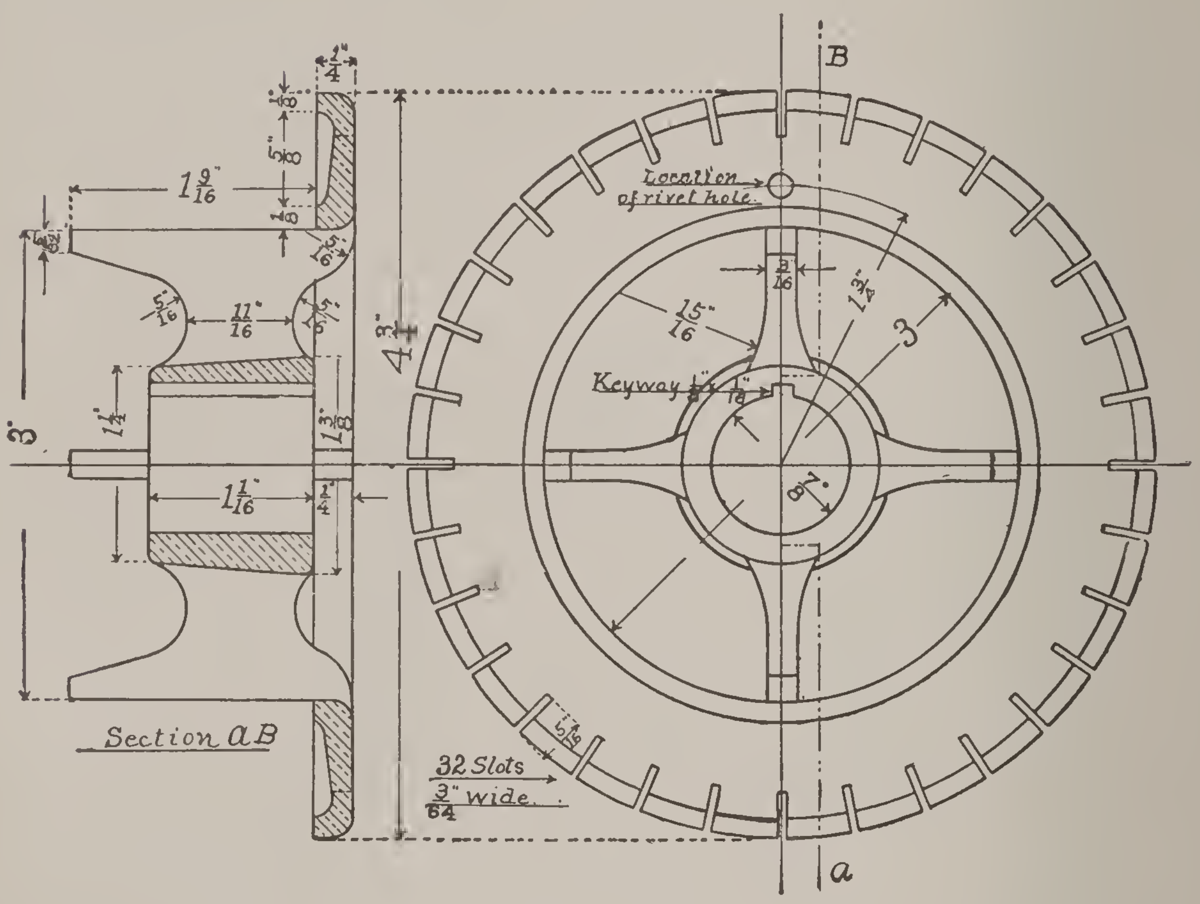


FIGURE 89.

sheets is not necessary. Bind the punchings to the flange with a few turns of fine wire; even then the ends of the arms should be below the top sheet. Fill the other spider, bind in the same manner, and put it in place on the shaft. Start the nut on a few turns. Remove the iron binding wires, and draw the spiders together by means of clamps pressing on the flanges. Be careful not to let any sheets get between the ends

of the arms. Two or three trials may be necessary to determine just the right number of punchings to use, in order that the core may be compact yet allow the arms to butt against each other. When the core is so solid that a thin knife blade cannot be inserted, screw the nut tightly, and remove the clamps. If the sheets are not even on their outside edges, take a light skimming cut in a lathe. Clamp the armature on the platen of a drill press and drill a $\frac{3}{16}$ inch hole entirely through the core and spiders, in the location shown in Fig. 89. Then drill the holes in the spiders a little larger, to $\frac{1}{4}$ inch in diameter, and drive a soft iron pin $3\frac{1}{4}$ inches long through the core.

The only special feature of the pulley is the long hub on one side that receives the end thrust and acts as an oil deflector. A set screw should be used, impinging on the key.

Bearings.—Gun metal, cast-iron, or babbitt metal is suitable for the bearings. They are plain, straight cylindrical castings (Figure 90). Chuck them, drill out the holes and ream to $\frac{5}{8}$ inch diameter. Then on an arbor turn the outside to $1\frac{1}{8}$ inches diameter, and square the ends. Mount them on an eccentric arbor and gash out the grooves in which the oiling rings run. Round off the resulting thin edge, file out the oil pocket and cut the grooves. Oiling rings may be of iron or brass, but may conveniently be cut from a suitable size of brass tube. In use these rings are half submerged in the oil that fills the wells, and as the shaft revolves they slowly turn, bringing up a constant supply of oil. Plugs of brass rod, turned to the specified dimensions, serve to cover the holes in the caps, yet allow inspection of the rings and admission of fresh oil. The linings are to be kept in place in the pedestals by means of protrud-

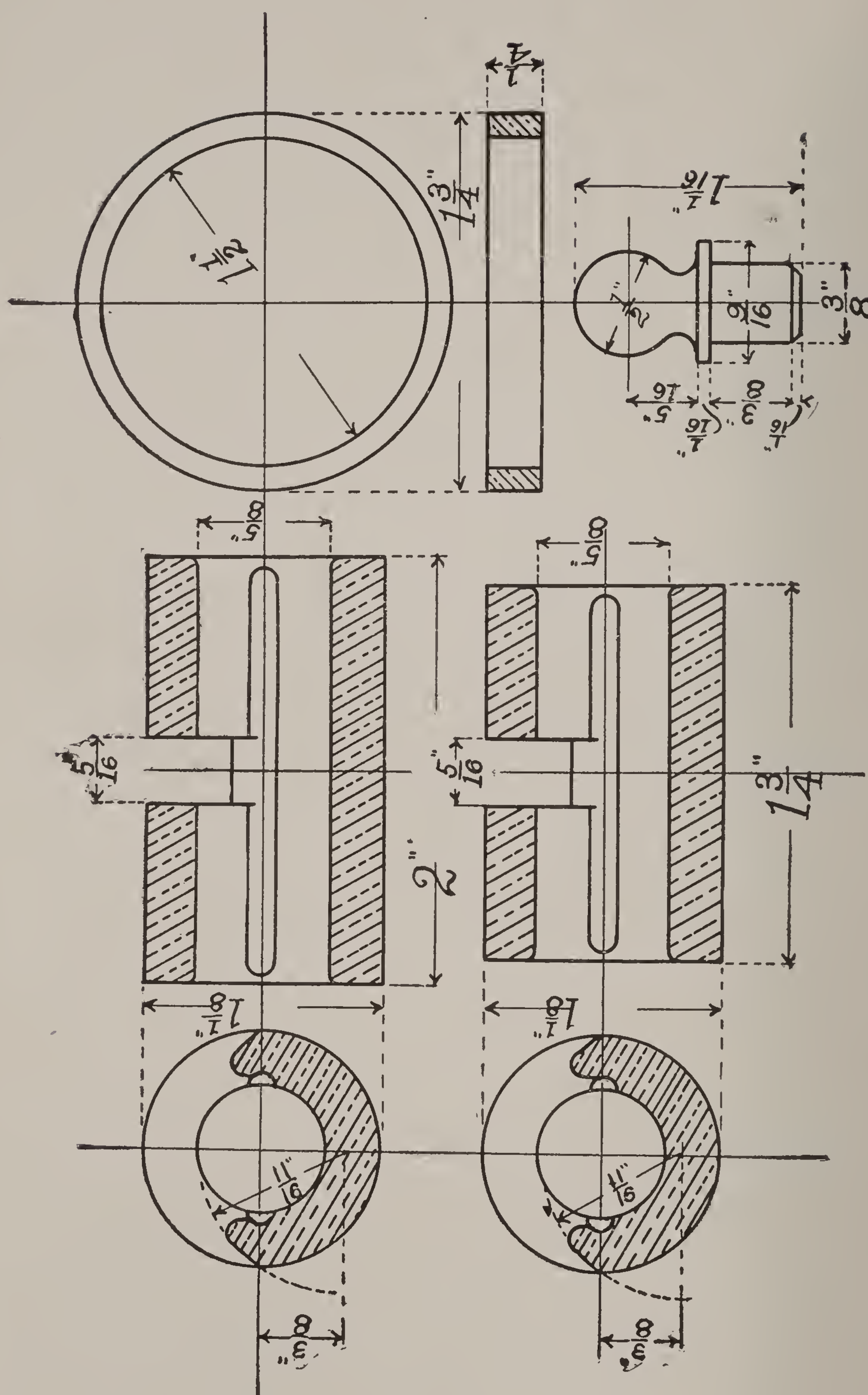


FIGURE 90.

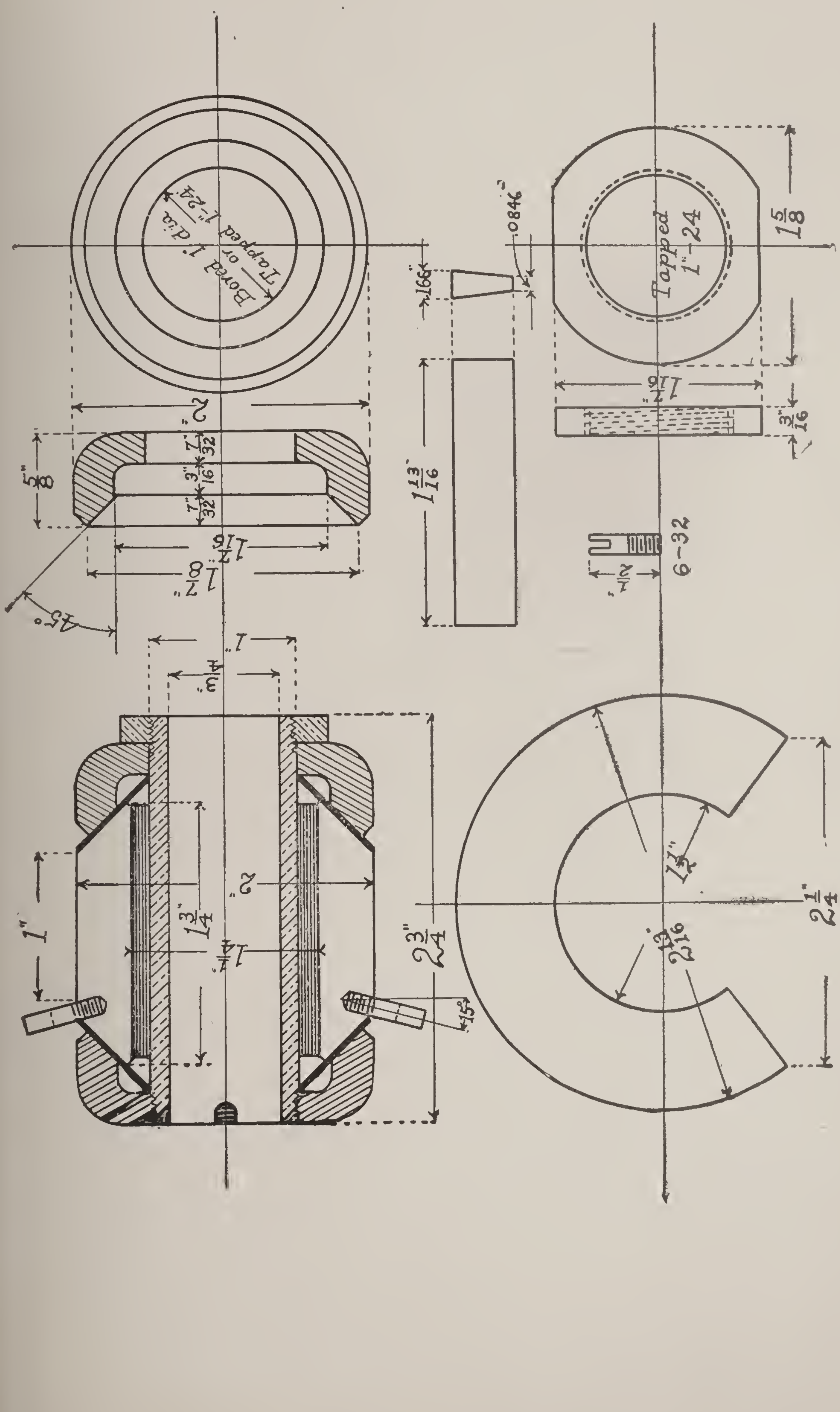


FIGURE 91.

ing $\frac{1}{4}$ inch steel pins, driven tightly through the caps. Set the armature in the center of the field, and allow $\frac{1}{16}$ inch end motion of the shaft before locating the pin holes in the linings.

Commutator.—This structure—the necessary evil of a continuous current machine—needs to be carefully made. Copper bars drawn wedge shaped for commutator segments are now easily procurable. For this dynamo 32 segments are required, measuring $1\frac{13}{16}$ inches long, $\frac{13}{32}$ inch wide, .166 inch thick at one edge, and .086 inch at the other. Prepare, also, 32 strips of mica, $1\frac{7}{8}$ inches long, $\frac{7}{16}$ inch wide, carefully gauged to $\frac{1}{32}$ inch thickness. Make a turned iron ring, measuring $2\frac{1}{16}$ inches inside diameter, and $\frac{7}{8}$ inch long; the outside may be of any convenient dimension not under $2\frac{1}{2}$ inches. Bevel one edge of the hole slightly for a distance of about $\frac{1}{8}$ inch. Set the segments and their insulations together in a circle and bind them with some twine or wire. Force the ring down over them. If the ring goes on too easily, insert a little more mica between some of the segments; if too tight, remove a little mica. Cut out the superfluous mica that protrudes into the interior and drive in a slightly tapering $1\frac{1}{4}$ inch arbor. Place in a lathe and turn the ends of the segments to an angle of 45°, letting the length over all be $1\frac{3}{4}$ inches. Force out the arbor.

To construct the retaining body of the commutator, use a piece of seamless brass tube, threaded at each end. Notch one end for engaging with a $\frac{1}{8}$ inch pin in the shaft. Two cast-iron flanges are to be made; one is threaded for screwing on the tube, the other is an easy sliding fit. Both are turned out with conical faces as shown. Around the middle of the tube wrap a strip of paper to a thickness of over $\frac{1}{8}$ inch. Use shellac freely and when dry it will be sufficiently hard to be turned in a lathe

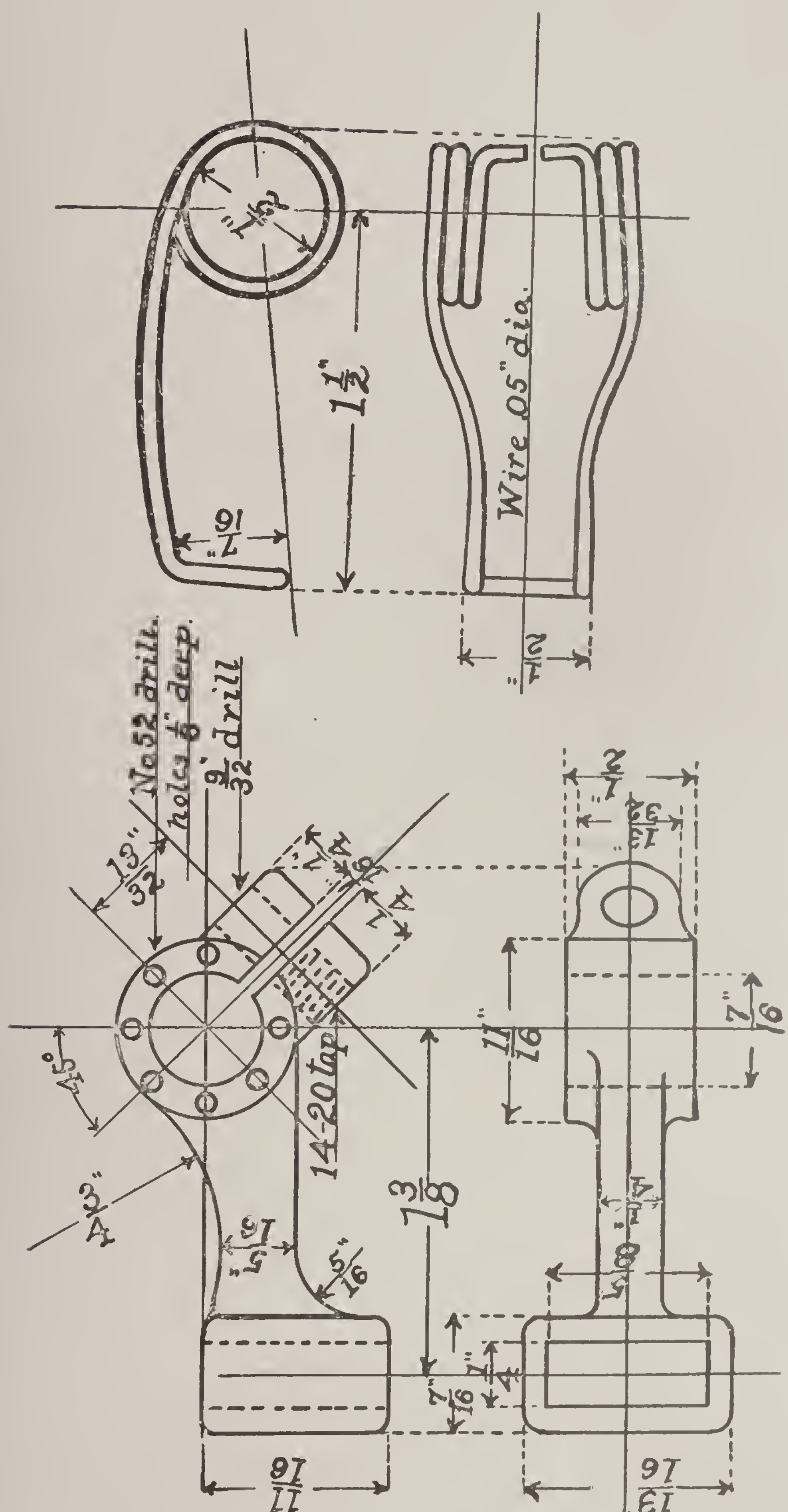


FIGURE 92.

to fit inside the segments. From very thin sheets of mica cut some rings $2\frac{13}{16}$ inches diameter, with $1\frac{1}{2}$ inch hole. Cut out sectors $2\frac{1}{4}$ inches wide as shown. By bringing the remaining corners together frustrums of cones will be formed. Shellac enough of these cones together, taking care to lap joints, until a thickness of $\frac{1}{32}$ inch is reached. Two such complete insulations are wanted. Slip one of these over the notched end of the tube and screw on the flange; slide on the segments, still held in the ring; lay on the other insulation, then the other flange, and tighten with the nut. Be careful not to get the segments twisted or skewed. Force off the ring, mount the commutator on a $\frac{3}{4}$ inch arbor and turn the outside smooth, finishing with fine sand-paper. Turn a slight portion of the circumference to an angle of about 15° and prick-punch each segment in the center of that space; then, tilting the commutator at the same angle in a drill press, drill with No. 30 size $\frac{3}{16}$ inch deep; tap out 6-32 threads and insert headless screws that are slotted to receive the armature wires. The conical spaces at the junction of flange and mica may be wound full of fine hemp twine and soaked with shellac. This will keep the mica from splitting.

Brushes, Holders, and Yoke.—Two kinds of brushes may be used, copper and carbon. The former, with its holder, is shown in Figure 93. All the parts are brass excepting the shoe or clamp-piece, which is more easily bent of sheet copper. In the casting for the body part drill a $\frac{7}{16}$ inch hole to fit the stud, and file smooth the cored rectangular slot for the brush. Tap for the two thumb-screws; finally saw the slot. The brush itself is made of thin planished sheet copper about .005 inch thick, cut in strips $\frac{1}{2}$ inch wide and $3\frac{1}{2}$ inches long. Build them to a thickness of $\frac{3}{16}$ inch, solder together at one end, and file

the other to an angle of 45 degrees to fit the commutator. The copper brush holder is shown in place on the machine in Figures 84 and 85. A suitable carbon brush holder is shown in Figure 92. The center is drilled $\frac{7}{16}$ inch as before, as it may be

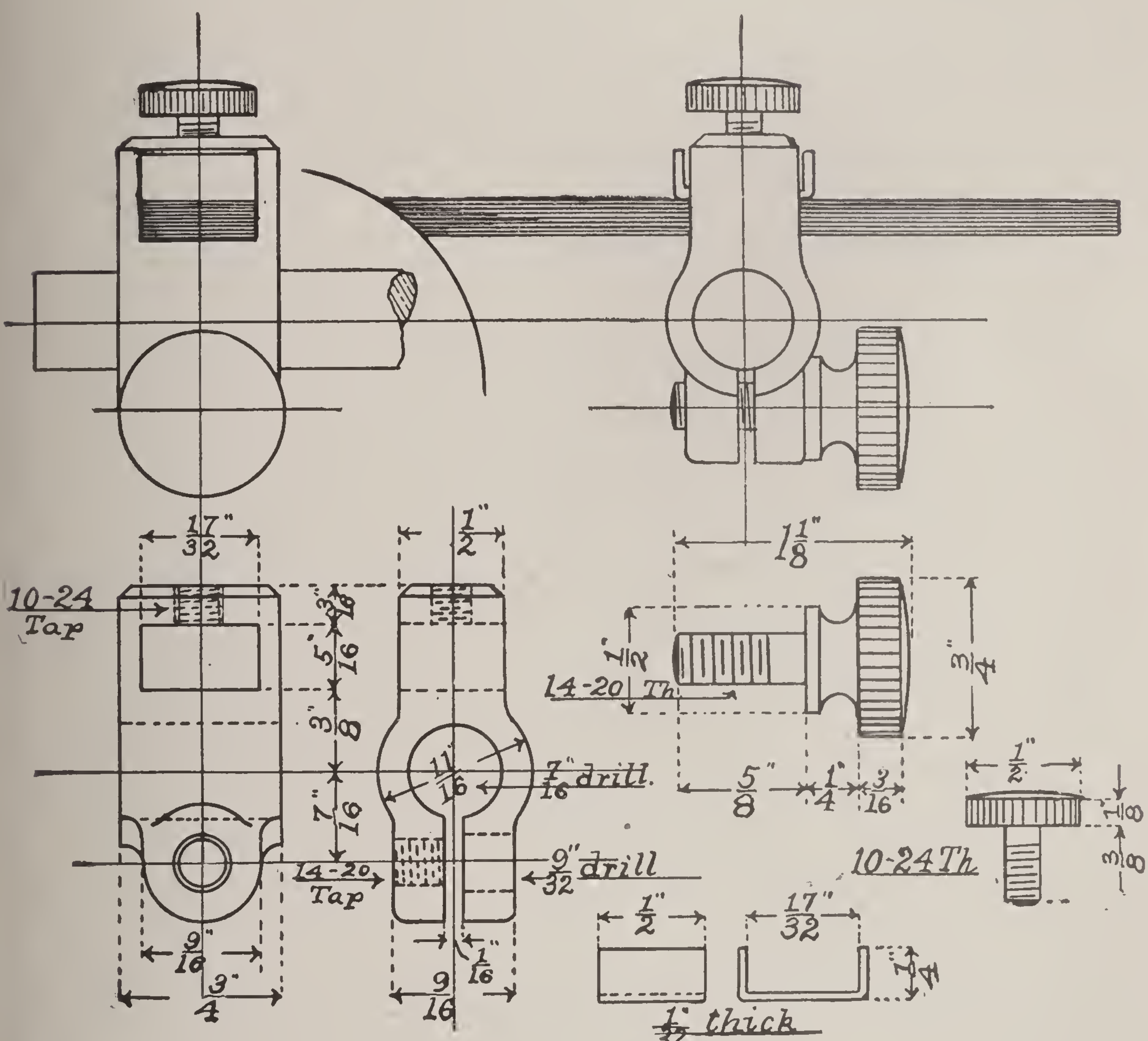


FIGURE 93.

used with the same stud as the copper holder. Drill a row of $\frac{1}{16}$ inch holes in both faces of the hub, about $\frac{1}{8}$ inch deep. Coil a spring of .05 inch diameter steel or brass wire; it will

be seen that the ends are to be bent at right angles to the spiral parts, and slipped into such of the holes as may be necessary to give sufficient pressure on the carbon. Let the

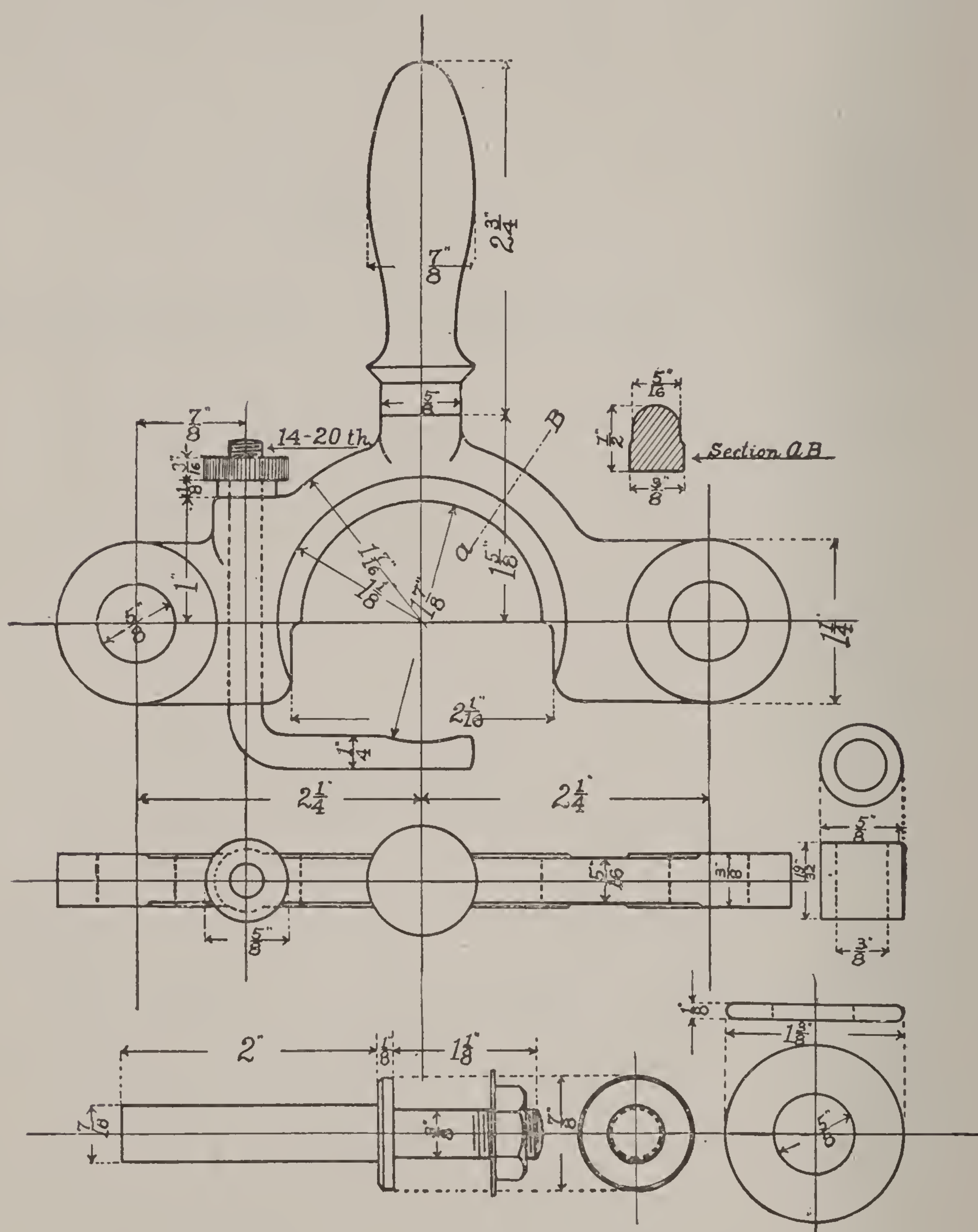


FIGURE 94.

brush, when new, be about $1\frac{1}{4}$ inches long, and slide freely but not loosely in the slot. As the holder seldom needs adjust-

ment an ordinary machine screw may be used to clamp it on the stud.

The devices which support the brush holders and permit their adjustment are called the yoke and studs. These, with the necessary insulations, are shown in Figure 94. Use cast-iron for the yoke, and any kind of wood for the handle. Bore out the semi-circular part to fit the groove that has been turned in the commutator end pedestal. Drill $\frac{5}{8}$ inch holes in the ends and file the circular faces flat, so that the studs may be properly held; drill a $\frac{9}{32}$ inch hole through the filled-in portion, for the L shaped tightening screw. Make the studs of $\frac{7}{16}$ inch round brass rod, turned to $\frac{3}{8}$ inch diameter at one end and threaded. The washer that serves as a shoulder should be driven on this end, soldered, and turned true. Use hard rubber for the washers and bushings. In Figure 95 the yoke, studs, and carbon brush holder are shown assembled, the yoke being inclined at some such angle as will be found necessary when in use.

Winding.—Data for winding the machine for either of two potentials, 110 volts and 50 volts, will be sufficient. The insulation and other preparations of the core will be identical for both.

Provide a quantity of thin tough paper in strips 4 inches wide, some discs 5 inch outside diameter, with $2\frac{1}{2}$ inch hole, and also a few pieces of thick drawing paper. Shellac may be freely used as an adhesive. Stick a 4 inch strip of paper all around the outside surface of the core, slit the edges and lap them over onto the flanges. Put, also, a layer of paper inside the core, lapping onto the flanges, and discs at each end lapping over to the other paper. See that every portion of the metal, excepting the limb of the spiders, is completely covered.

When dry put on a second layer, being careful to bring the lapped joints in different places. Add a third and fourth layer, or more, until the insulation is $\frac{1}{32}$ inch thickness in all. The

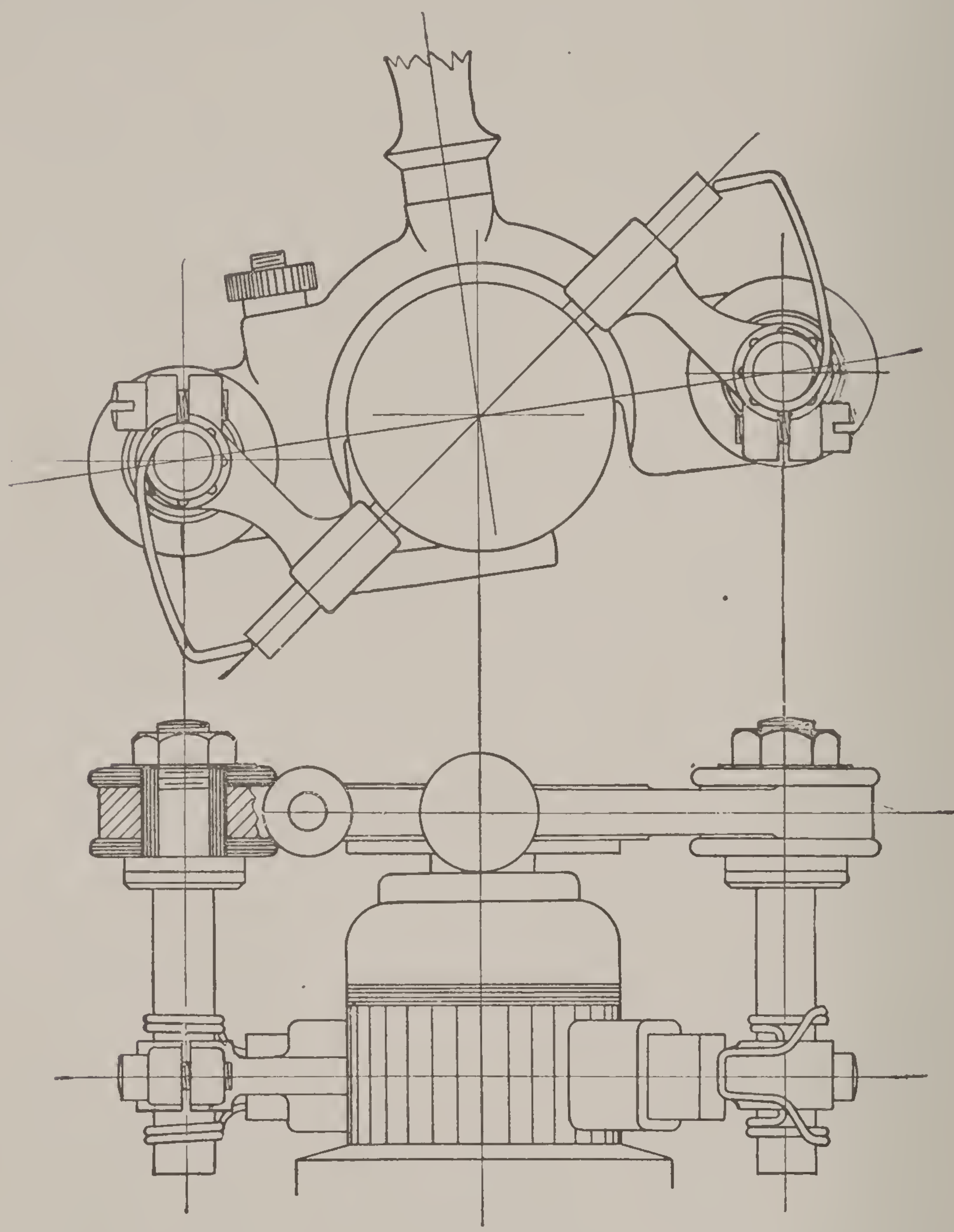


FIGURE 95.

builder may substitute thin muslin for one layer of paper with good results.

Make four troughs of the drawing paper bent in the shape shown at "*a*" in Figure 96. They may be formed of rectan-

gular pieces cut $3\frac{3}{4}$ inches long and $2\frac{3}{4}$ inches wide, the lips being turned over on the long edge $\frac{3}{8}$ inch back. Make, also, 32 smaller troughs of strips $3\frac{3}{4}$ inches long and 1 inch wide. Bend them over a slat about $\frac{1}{4}$ inch thick, so that 8 of them, when shellacked together, may be set inside of "*a*" and appear as shown at "*a* and *b*." Slip these insulations in between the

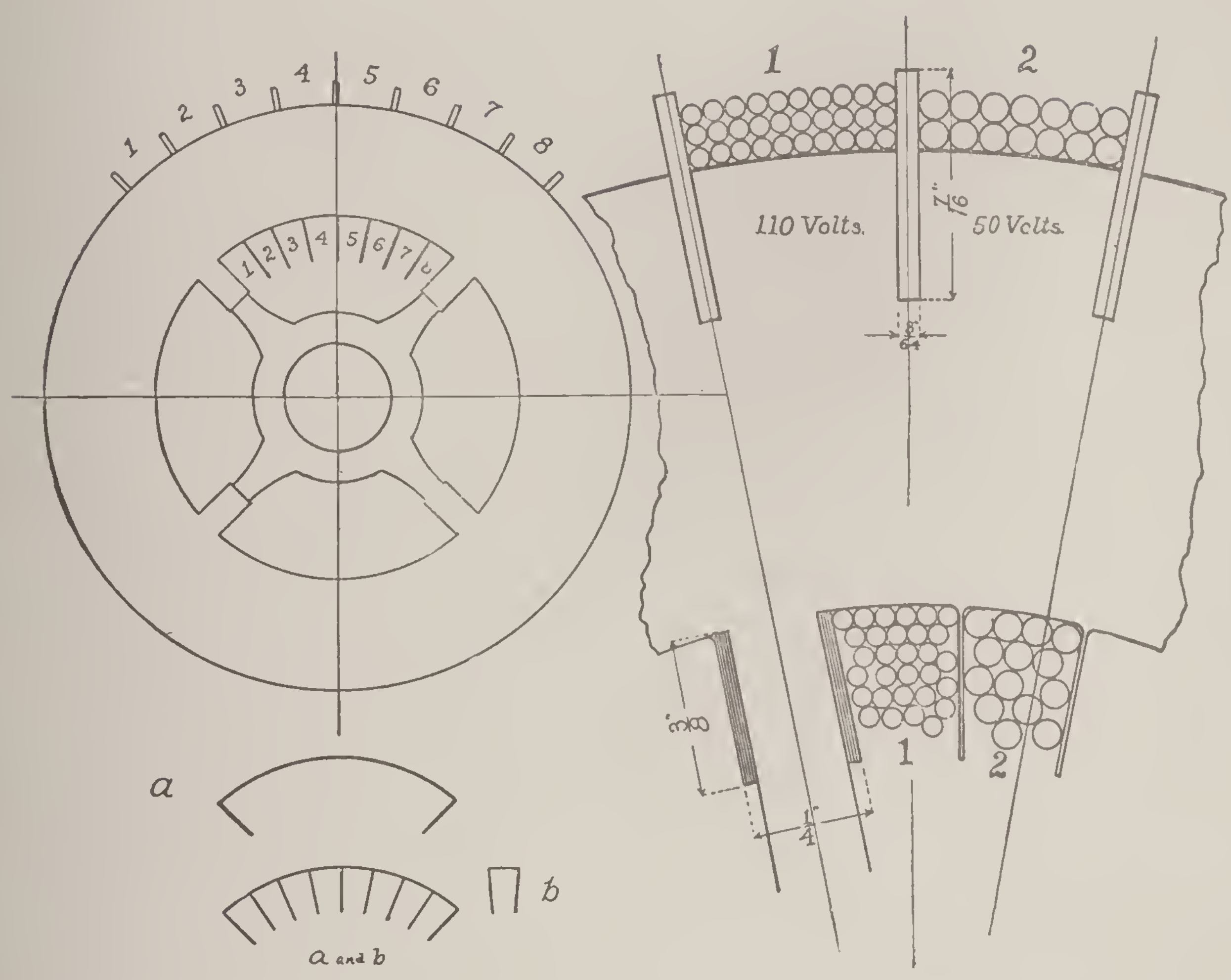


FIGURE 96.

arms of the spider and shellac them in place. One is shown in Figure 96. Fit 8 wedge-shaped pieces of soft wood into the troughs to keep them rigid. With the point of a knife peel around the rim of the spider for the slots that were sawed in the flanges, and when located cut through the insulation radially

and drive in pegs of hard fibre. They may project $\frac{3}{16}$ inch or $\frac{1}{4}$ inch, and superfluous parts cut off later.

For 110 volts provide 3 pounds No. 20 wire (.032 inch diameter). Cut off a length of about 29 feet, and beginning at each end wind it on two slim shuttles, half on each. These shuttles may be of maple, about 1 foot long, 1 inch wide and $\frac{1}{8}$ inch thick, notched at each end deep enough to hold the wire. By aid of these the wire may be easily threaded through the center of the core without injuring the insulation.

From one of the shuttles wind five turns onto the core, letting the first turn occupy the center of the space between two pegs, and the fifth turn touching the pegs. In the trough the wires will be disposed so as to form $\frac{5}{6}$ of a layer. From the other shuttle wind five more turns, thus making one complete layer on the outside surface of the core; on the inside the first layer will receive a final turn and the second four turns. These successive stages may be easily followed by reference to the enlarged view in Figure 96. Shellac these wires thoroughly, and, when dry, wind another series of ten turns, five from each shuttle. Shellac and wind 10 more turns. The device of winding with the two shuttles is to allow both ends of the coil to be left on the outside layer, where connections may be easily made and dangers from short circuits lessened. It may be found that 29 feet is not quite the right length for the coil and the others may be cut more exactly.

When the shellac on this coil is dry remove the wedge from section 2, and wind 30 turns as before; then in section 3, and so on until all the spaces are filled. Wind the wires tightly, straightening out the bends, and pressing each coil firmly in place. Do not neglect the compactness of the coils in the

troughs, as the entire winding must be so disposed as to keep the armature balanced.

Twist the end of one coil with the beginning of the next, so that, electrically, there will be an unbroken circuit. Slip the commutator in position. Remove the insulation from the wires where they will touch the connection screws. Lead the wires that connect coils 4 and 5 to the segment that is opposite the spider arm at 1. Solder both wires in the screw slot and let the other 31 loops follow in successive order. The appearance will then be as if, after connecting the wires straight, the commutator had been turned one-eighth of a revolution. This lead is given to the wires simply for the sake of getting the yoke and brushes into a more convenient position.

For 50 volts use 3 pounds No. 17 wire (.045 diameter), wound in two layers, seven turns per layer, as shown in Figure 96. Each coil will require about 14 feet of wire. If there is difficulty in getting a slot in the commutator screw large enough to hold both the connecting wires, the two may be soldered together just back of the commutator, one of them cut short, the other flattened so as to enter the slot. Shellac the loops to keep the insulation from unraveling.

Binding wires must be wound on to prevent the armature coils from flying off by reason of centrifugal force. Close up to the pegs and in the central space wrap a few turns of thin paper, held with shellac, and wind 10 or 15 turns of .015 inch diameter brass or German silver wire on each of these strips. Do this winding in a lathe, very slowly, so as to be close and tight; before loosening the tension solder the wires together. Cut off the pegs that project above these binding wires.

Spools, as shown in Figure 97, are necessary for holding the

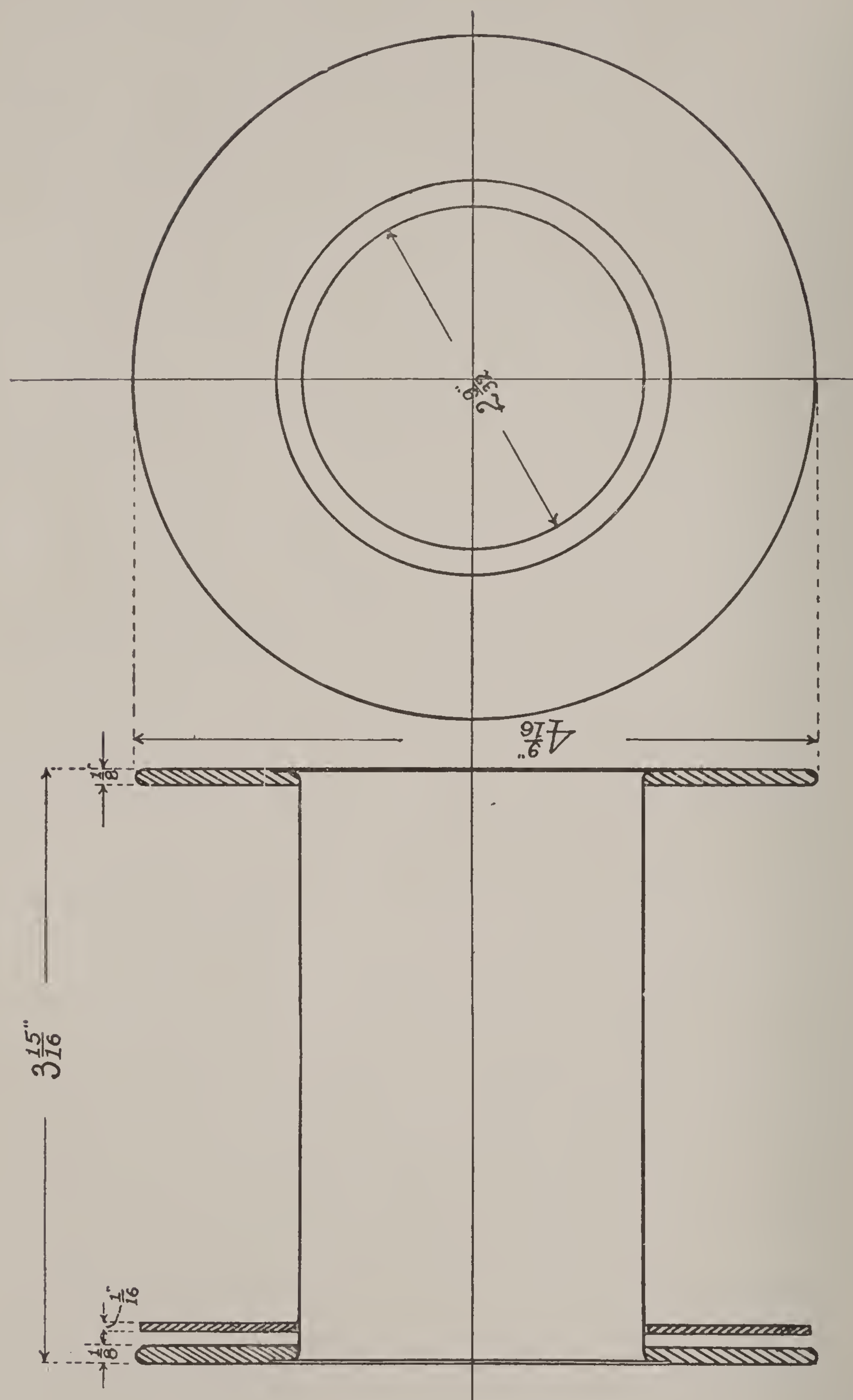


FIGURE 97.

field coils. They can be made of leatheroid or fibre washers, held together by a tin or sheet brass tube. A third thinner washer is useful for keeping the starting end of the wire from the main part of the coil. This one has a larger center hole than the outside ones and is notched to allow the wire to pass under. Mount the spool in a lathe on such an arbor that the washers may be supported. Wrap several layers of paper on the tube, letting the edges join tightly against the end washers, passing under the loose one. Draw a considerable length of wire through the notch, and wind one turn around the spool in the opposite direction from which the lathe runs. Press the loose washer against this single turn and wind several layers in the main part of the spool; shellac on a layer of thin paper, then from the wire on the arbor continue a few turns in the narrow space between the two washers; then several more main layers, and a few more from the end length, until the requisite amount is reached. If the wire is fine the ends may finally be passed through small holes near the edge of the washers; or, if large, bind the ends by passing twine around them and through several small holes.

About 2000 ampere turns are required on each spool for field excitation, in order to generate the stated potentials on open armature circuit, when no load is on. As the load is added an increase in magnetizing force is required and the following data makes necessary allowance for this requirement. The amounts stated are for one spool.

110 VOLTS.

1. Series:—$8\frac{1}{2}$ pounds No. 13 (.072 inch diameter) double cotton covered wire; 45 turns per layer; 12 layers.

2. Shunt:—$4\frac{3}{4}$ pounds No. 24 (.02 inch diameter) double cotton covered wire; 120 turns per layer; 30 layers.

3. Compound. (*a*) Shunt:—5 pounds No. 24 (.02 inch diameter) single cotton covered wire; 150 turns per layer; 28 layers.

(*b*) Series:—$2\frac{3}{4}$ pounds No. 14 (.064 inch diameter) double cotton covered wire; 47 turns per layer; 4 layers.

50 VOLTS.

1. Series:—9 pounds No. 10 (.10 inch diameter) double cotton covered wire, 33 turns per layer; 9 layers.

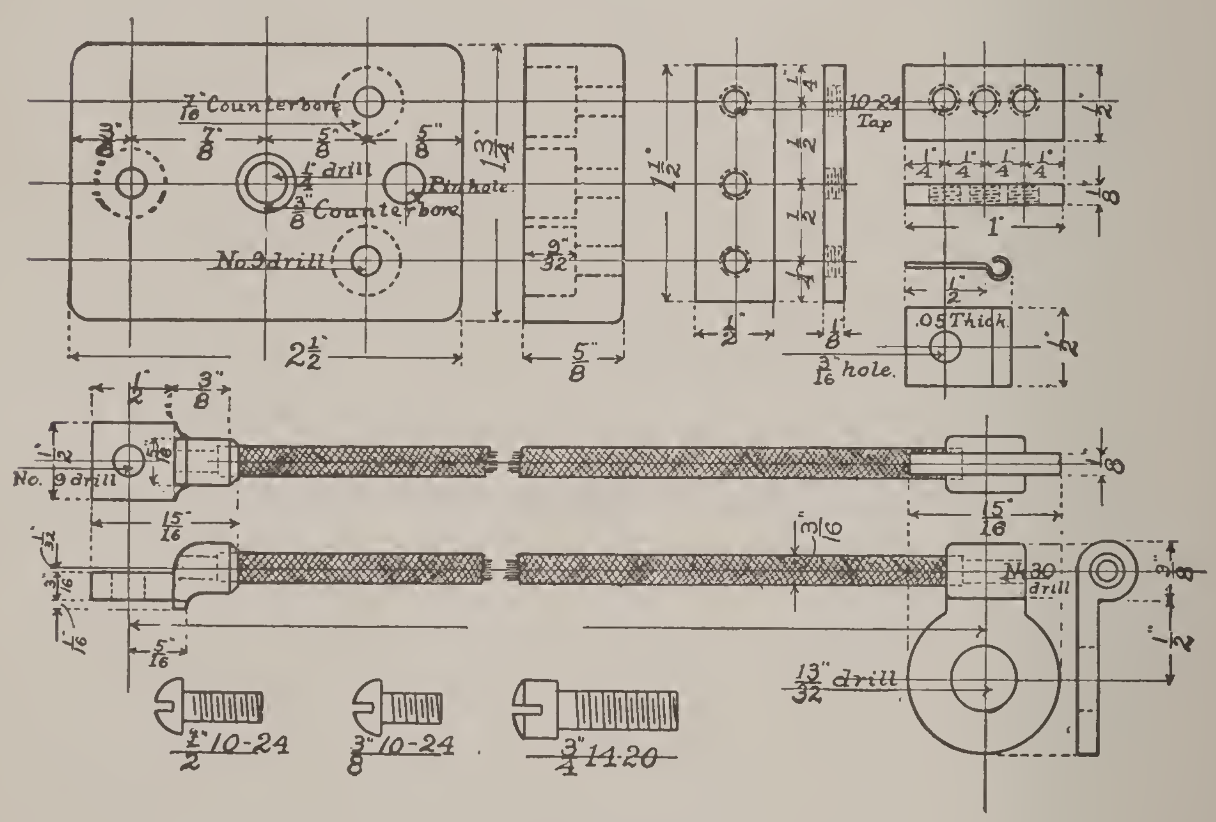


FIGURE 98.

2. Shunt:—$8\frac{1}{2}$ pounds No. 20 (.032 inch diameter) single cotton covered wire; 104 turns per layer; 28 layers.

3. Compound. (*a*) Shunt:—5 pounds No. 21 (.028 inch diameter) single cotton covered wire; 117 turns per layer; 22 layers.

(*b*) Series:—$2\frac{1}{4}$ pounds No. 13 (.072 inch diameter) single cotton covered wire; 45 turns per layer; 3 layers.

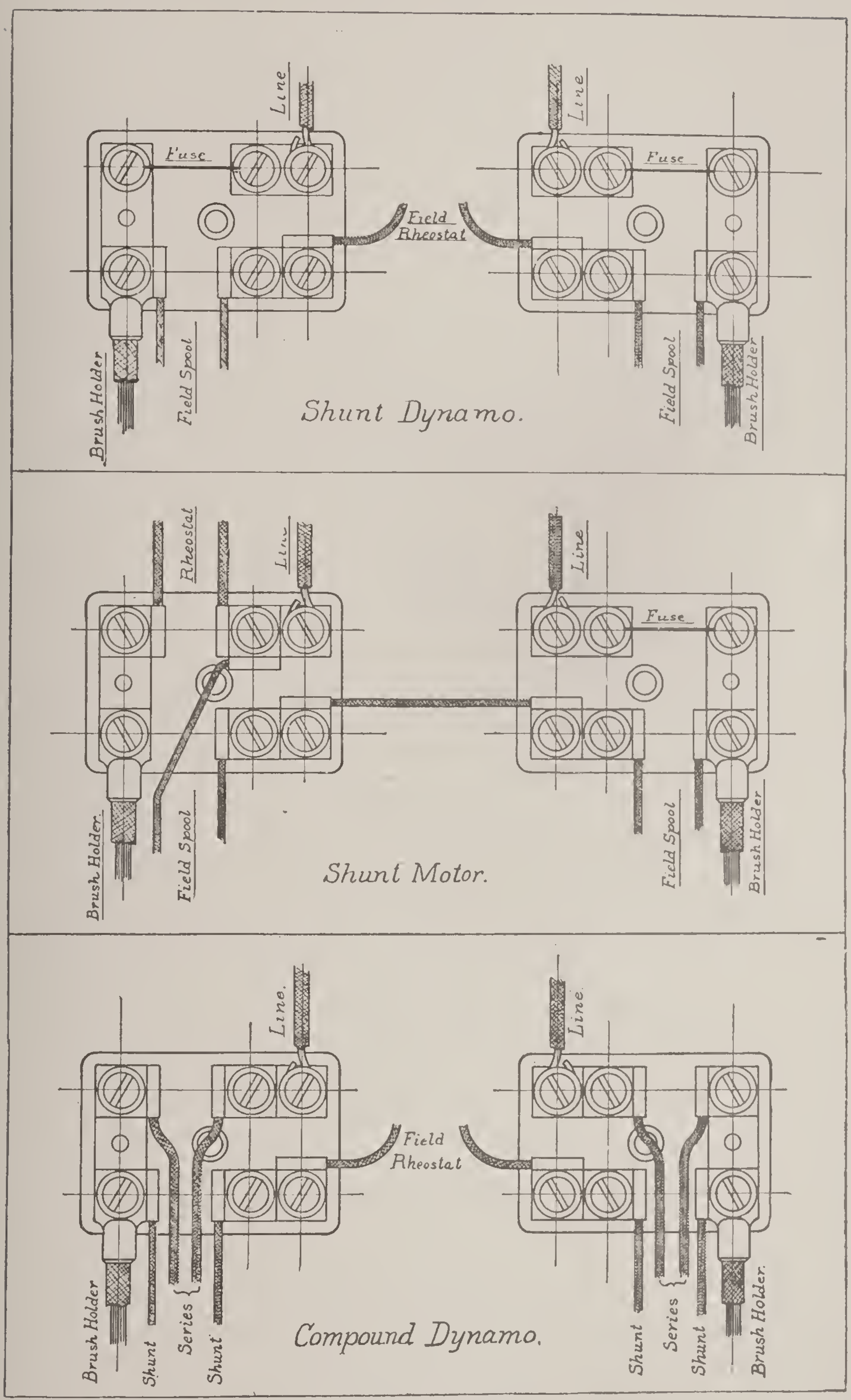
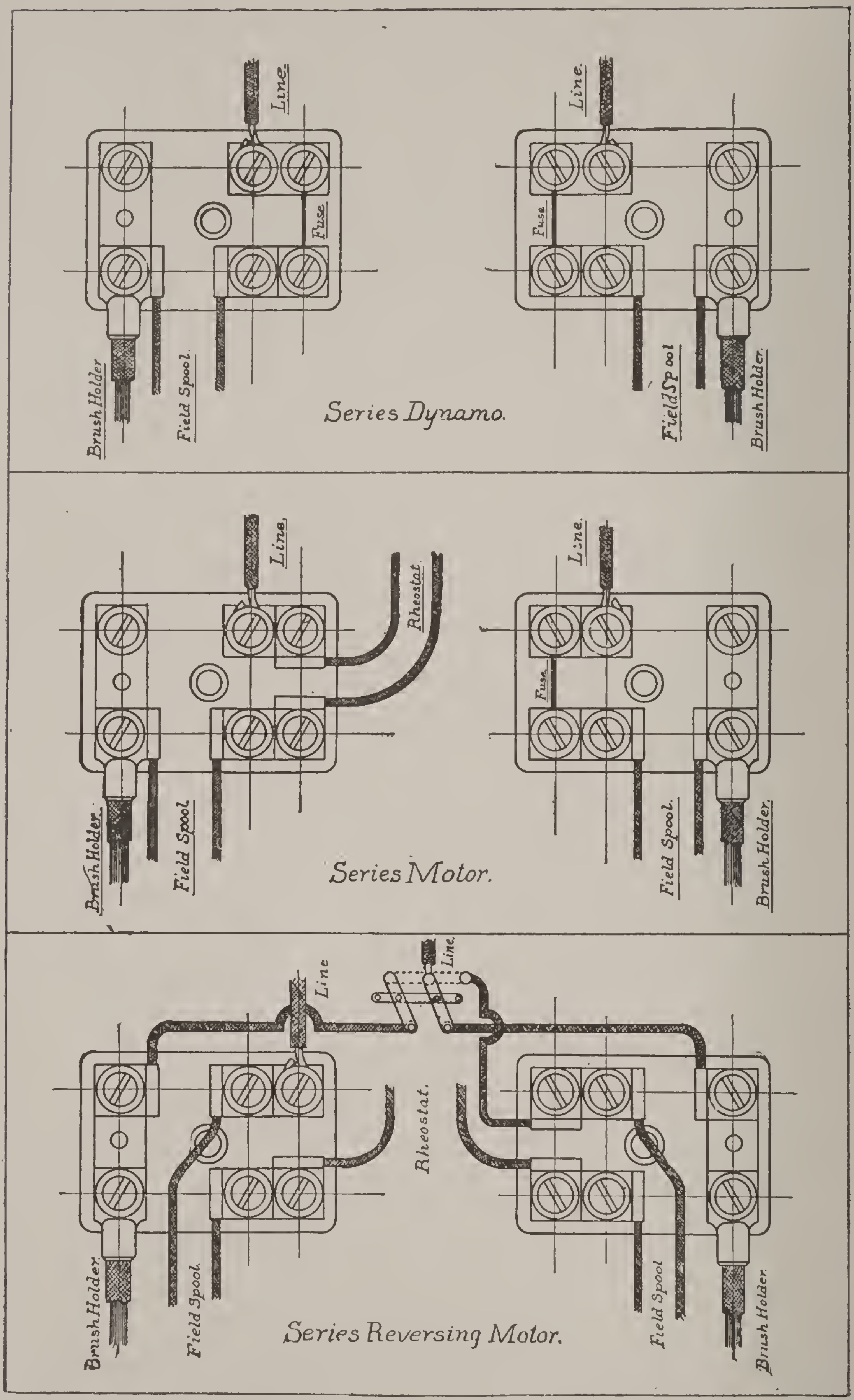

Line
Fuse
Field
Rheostat
Brush Holder
Field Spool
Shunt Dynamo.
Rheostat
Line
Fuse
Brush Holder
Field Spool
Shunt Motor.
Line.
Field
Rheostat
Brush Holder
Shunt
Series
Shunt
Compound Dynamo.
Brush Holder.

FIGURE 99.



Line.
Fuse
Brush Holder
Field Spool.
Series Dynamo.
Line.
Fuse
Field Spool
Brush Holder.
Line.
Rheostat
Brush Holder.
Field Spool
Series Motor.
Line.
Fuse
Field Spool.
Brush Holder.
Line
Line.
Rheostat.
Brush Holder.
Field Spool.
Series Reversing Motor.
Field Spool
Brush Holder.

FIGURE 100.

Where possible, an even number of layers has been specified, in order to bring both ends of the wire at the same end of the spool, and be close to the connection board on the machine. In a compound winding insulate well the ends of the shunt coils, or they may short circuit with the series turns that are wound on over them.

Connections.—Allowance is made for using the machine in a variety of ways. Aside from the winding, the method of arranging the exterior connections depends largely on the particular use to which the machine is put. A connection board is provided beside each field spool, with a set of contact clips that may be so varied in location as to make any of the combinations shown in Figures 99 and 100. Details are given in Figure 98. Use well dried hard wood for the bases, and after drilling soak them in melted paraffin. Make blocks of sheet brass and attach them by means of screws in the center holes. Mark the locations of the other screw holes on the front, and drill for $\frac{1}{8}$ inch or more, so that the short screws may enter the base a little and keep the blocks from slipping. Use sheet copper for the terminals, into which the ends of the fields coils are soldered. Standard fuses of 4 amperes for 110 volts and 10 amperes for 50 volts should be located as shown, to prevent accident from short circuits or overloading. After securing to the pole pieces by means of the 14-20 screws, drill $\frac{1}{4}$ inch holes through the wood, as shown, and for a short distance into the iron, and drive in wooden pins to keep the boards from moving. It is impracticable to use screws in this place, as their heads would be directly under the fuses.

Incandescent lamp cord may be substituted for ordinary cables if the latter are not available. Let the insulation enter the cast brass terminals a short distance and solder the wires into holes

drilled to fit. The cables may measure 10 inches long between centers of terminals, but the builder may vary the length to suit.

Testing and Using.—It will be well to assemble the field magnets and spools, without the armature, and arrange the field connections. So connect the wires that the current may circulate in both coils in the *same* direction. Send a current from a battery, or other source of continuous current, through the coils, and test the pole pieces for magnetism. The whole upper casting should be magnetized to one polarity, the lower pole to the other.

The builder will have to determine from the nature of the work to be done just which set of connections to adopt. Having these arranged, the screws which hold the boards in place may be withdrawn and the upper pole piece removed. Put the armature, yoke, and brush holders in position, replace the pole piece and attach the connection boards. If to be used as a dynamo, equip with copper brushes; if a motor, use carbon brushes.

On general principles a dynamo or motor will run in one direction as well as in the other. The ordinary direction usually adopted is such that if the observer were looking at the commutator end of the shaft, the armature will rotate in the direction opposite to the hands of a clock. With copper brushes it will not be possible to run this machine "clockwise," unless the direction of the "lead" to the commutator connections be reversed. With carbon brushes, however, either direction of rotation is allowable.

Before starting see that the wells in the pedestals are filled with thin oil, and that nothing interferes with the proper movement of the oil rings.

If the machine is to be used as a series dynamo send the current from a strong battery, such as several cells of the bi-chromate type, or other source of continuous current, through the circuit by connecting with the "line" terminals. If the armature tends to turn in the direction in which the brushes point, reverse the connections with the spool terminals, so that the current will flow through the fields in the opposite direction and magnetize the poles with the other polarities. Again connect the battery, and if the armature tends to turn against its brushes, everything is right for generating. Drive the armature, using a pliable belt, at 2600 revolutions per minute. Connect to its circuit and the machine should instantly begin work. Adjust the brushes to the non-sparking point.

If a shunt dynamo is desired, the battery current may still be used, but in order to send any current around the fields a rheostat, or resistance, should be connected in the armature circuit. This may conveniently be done by removing one of the cables and inserting a suitable resistance, say 10 to 20 ohms, in its place. Cut out all the resistance in the field rheostat, or simply connect its terminals with a short wire. So connect the ends of the field coils to the brass blocks that, when the current is flowing, the armature will tend to turn in the direction of its brushes. Remove the battery wires and replace the cable. Drive the armature at 2600 revolutions per minute. If the machine does not generate at once shift the brushes slowly back and forth past the neutral point. If it still fails to generate, examine the fields for polarity, to see that there has been no mistake in connecting the coils. Separately excite the fields and see if the armature will generate. If it will not, then the trouble is in the armature itself, and will require examination for grounds, short circuits, or open circuits. After the

machine has been put in working order connect the lamp or other circuit and adjust the potential by means of the field rheostat.

For a compound dynamo divide the tests into two parts. First make it generate as a series machine, leaving the shunt terminals disconnected; then remove the series clips and make it generate as a shunt dynamo. Reconnect the series coils and the proper working conditions should result.

The diagrams for motor connections plainly show the arrangements. Starting rheostats must be used in the armature circuit to prevent burning out from overcurrent. If used on a 110-volt circuit such a rheostat may well have an initial resistance of 15 ohms. The use of motors on arc light circuits is dangerous, and is not often allowed.

A good lubricant for the commutator is a mixture of vaseline and graphite; keep a cloth saturated and occasionally rub it on the commutator while the armature is running. Do not let the brushes spark; if such action shows itself immediately investigate the cause and remedy it. These causes may be: (1) overload; (2) brushes off the neutral point; (3) rough commutator—smooth it with sandpaper on a piece of wood and rubbed on the revolving surface; (4) bad brushes—see that they are clean, fit the commutator, and do not touch more than two segments at once.

It is well to bolt the machine to a wooden bed plate that can be given several inches of motion by means of a screw. Proper tension can then be secured for the belt, and insulation from the ground.

CHAPTER XI.

HOW TO BUILD A ONE-HORSE POWER MOTOR OR DYNAMO.

In presenting this chapter the writer has had a variety of considerations in mind which were regarded as of cardinal importance. Amateurs have limited tool facilities, and in this motor, machine work has been reduced to the minimum. The use of a planer has been avoided. A lathe can do all the work. A milling machine will be found convenient but it is not essential. The field casting is in but one piece. Even the arms for supporting the bearings are integral with it. The poles are salient, and "end on" towards the armature; the lines of magnetic force do not have to bend in order to go through the armature core. The field coils are nearly covered by the iron, thereby making the wire most useful in producing the magnetism, and the leakage of magnetism is very small.

No exterior magnetism can be felt, and any additional devices for adapting the machine for particular applications can be bolted to the machine at will. Mechanical joints being absent there is the best of magnetic circuits. Still the field coils can be wound in a lathe upon a form and slipped into position. Winding the field coils in sections allows the wires to be con-

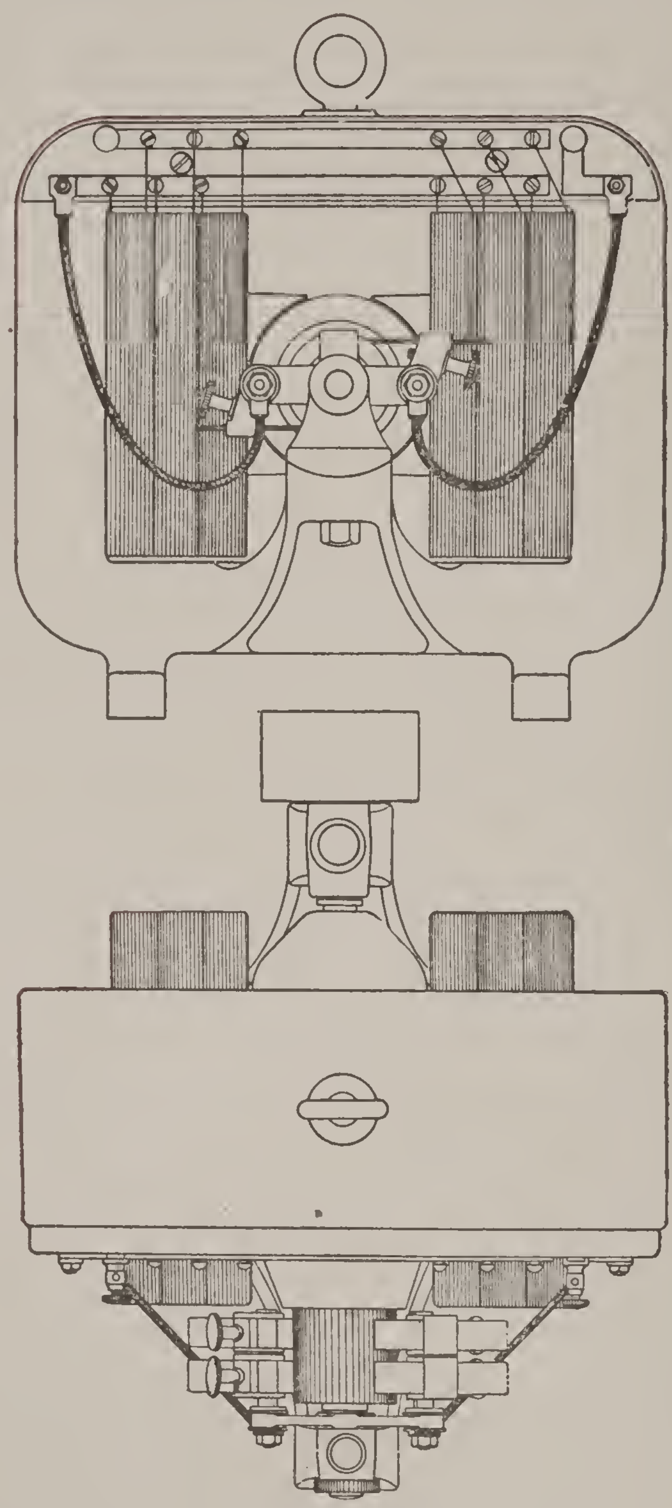


FIGURE 101.

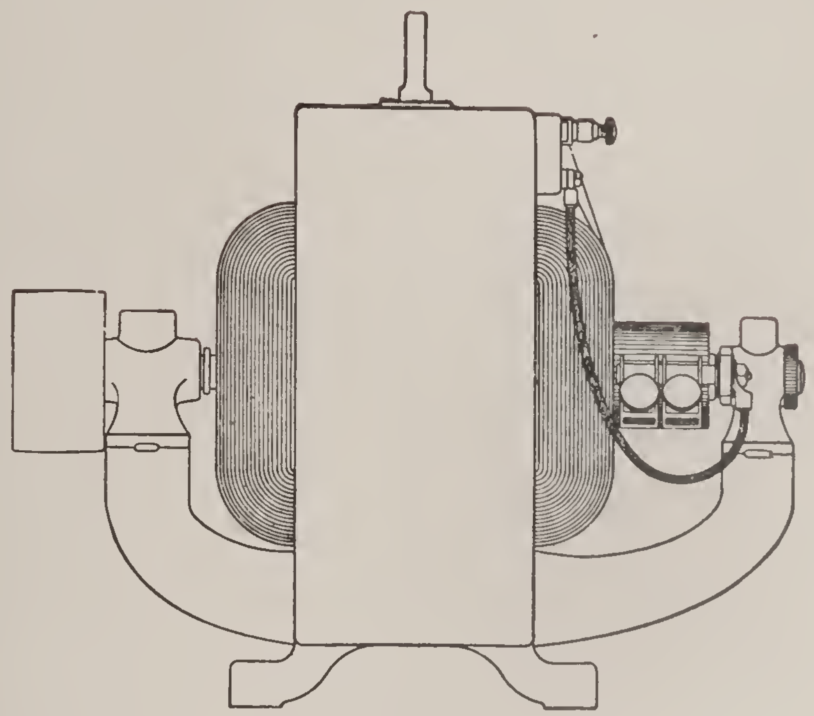


FIGURE 102.

nected for a series motor or dynamo, or in series for a shunt machine.

The armature is in the center of gravity of the machine and protected from danger or damage from the outside. The core is of the ordinary Siemens drum type, thus most easily made and wound. The large mass of iron in it and the field keeps the commutator free from sparks. The bearings are very simple and practically self oiling.

The motor is of one-horse power capacity, will pump water, blow a large organ, run a small machine shop or printing office, will drive a 16-foot boat five or six miles per hour. As a dynamo it will run one 2000 c. p. or two 1200 c. p. arc lamps, or ten 16 c. p. incandescent lamps, or a sizable plating establishment.

The motor may be belted direct to shafting, or by screwing

extra bearings to the frame the speed can be reduced by gearing.

The construction of the field is plain from the accompanying drawing.—Figure 103.

No attempt has been made to make this a lightweight casting. It weighs a little over one hundred pounds. The efficiency of a motor and the conditions of non-sparking with a change of load demand a very powerful magnetic field. It is false economy to begrudge iron for this purpose.

Several ways are possible in making this pattern for the field casting. A good method is to part the rectangular frame on a line even with the lower surface of the pole pieces. The parts for the pole pieces themselves are loose but are to be recessed about half an inch into the frame. By this construction of the pattern coring will be avoided, also expense of the core-box, and smoother castings are obtained.

On the ends of the arms where the pedestals for the bearings rest, the middle part is cut away, strips on the inner and outer edges alone receiving the machine finish. The bottoms of the bearings, Figures 104 and 105 are to be treated in the same way. A single bolt through each arm holds the bearings in place.

With the castings at hand, the builder may, if he will, work on the field first. The holes are to be drilled as shown, the four through the legs for bolting to the base board on which the machine is finally to stand. The holes through the ends of the arms are $\frac{1}{16}$ inch larger than the bolts, to allow room for adjustment of the bearings. The tapped hole in the top is adapted to receive an eye bolt for convenience in lifting the machine. Two tapped holes on the upper front part of the

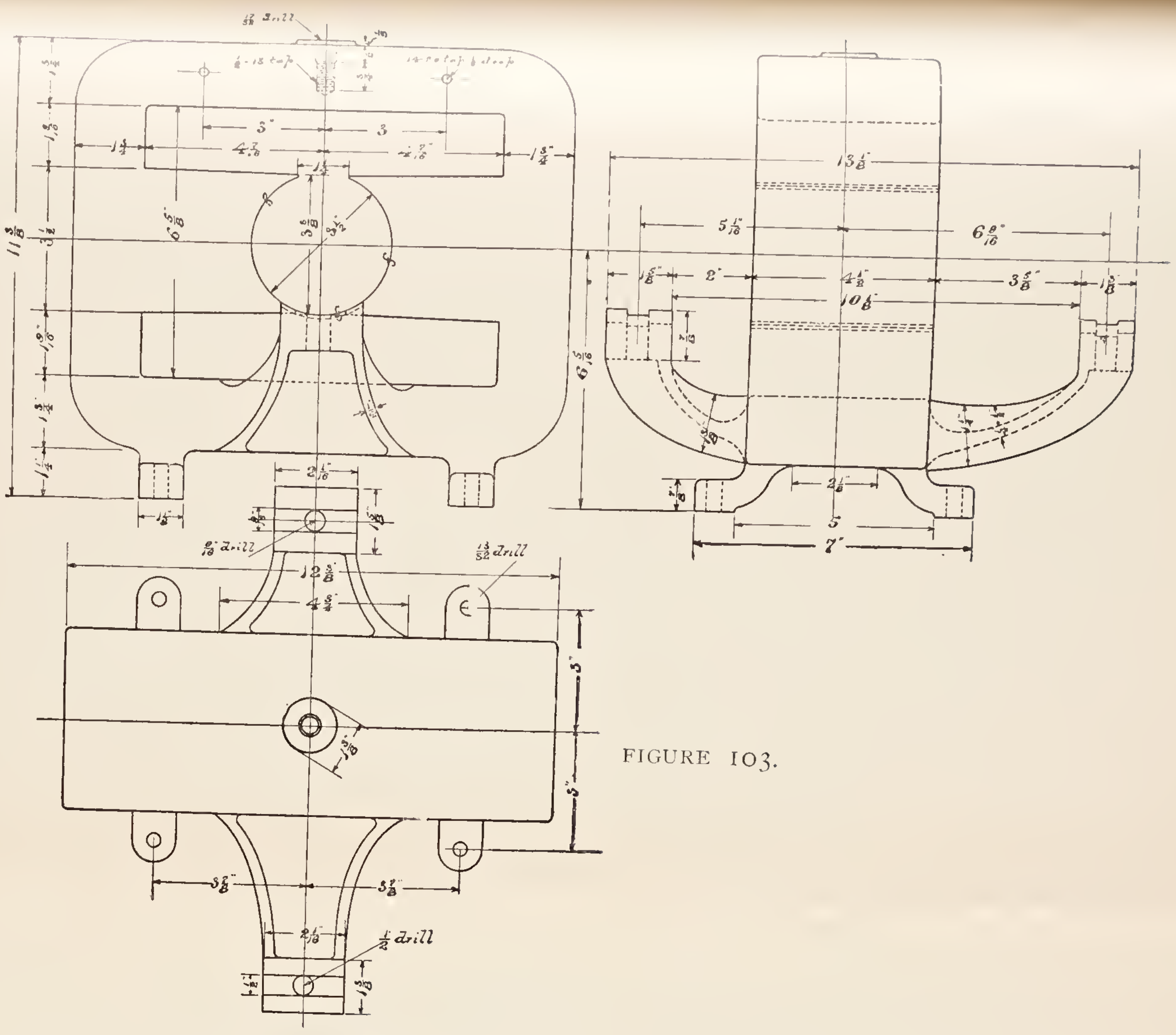


FIGURE 103.

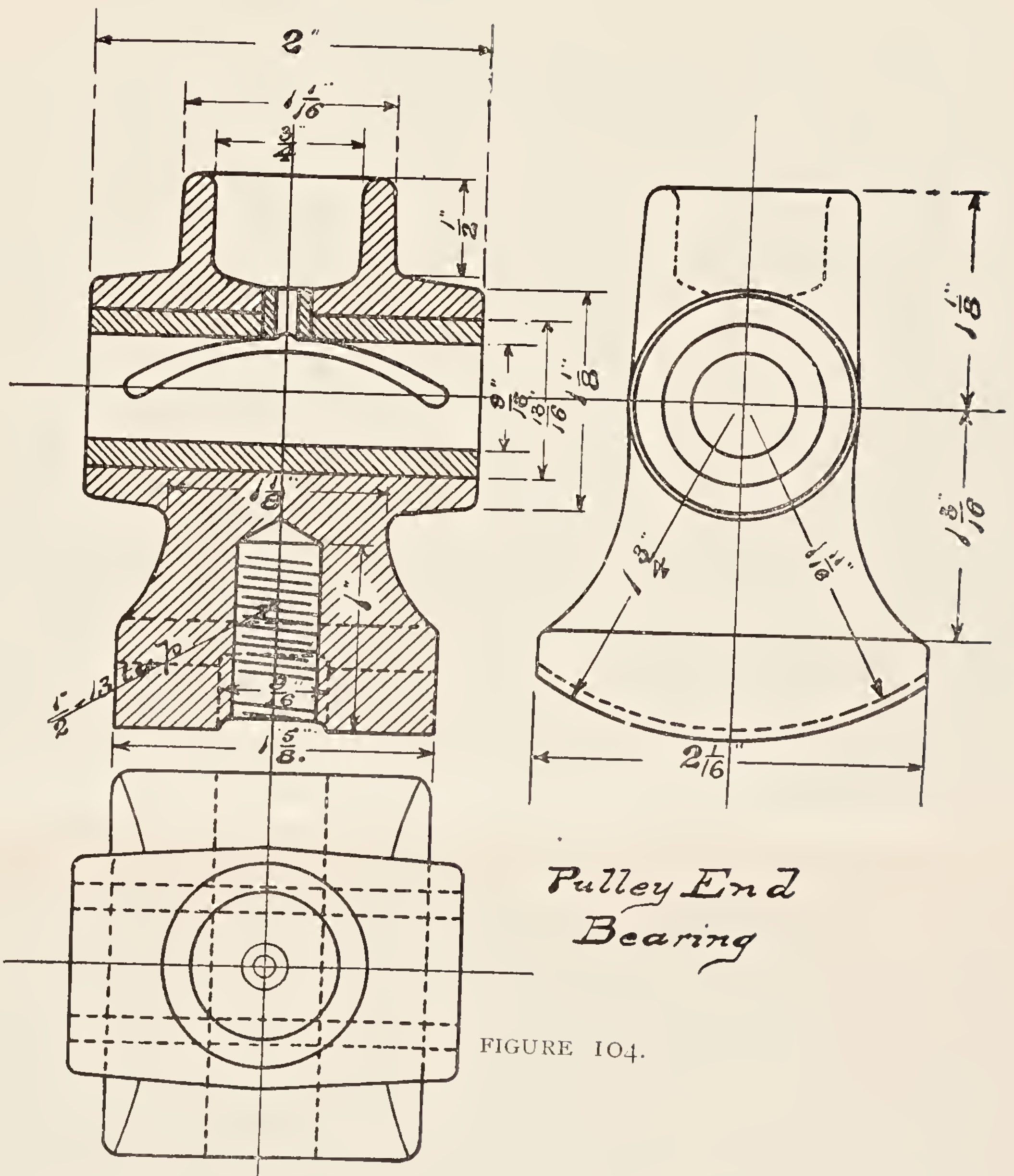


FIGURE 104.

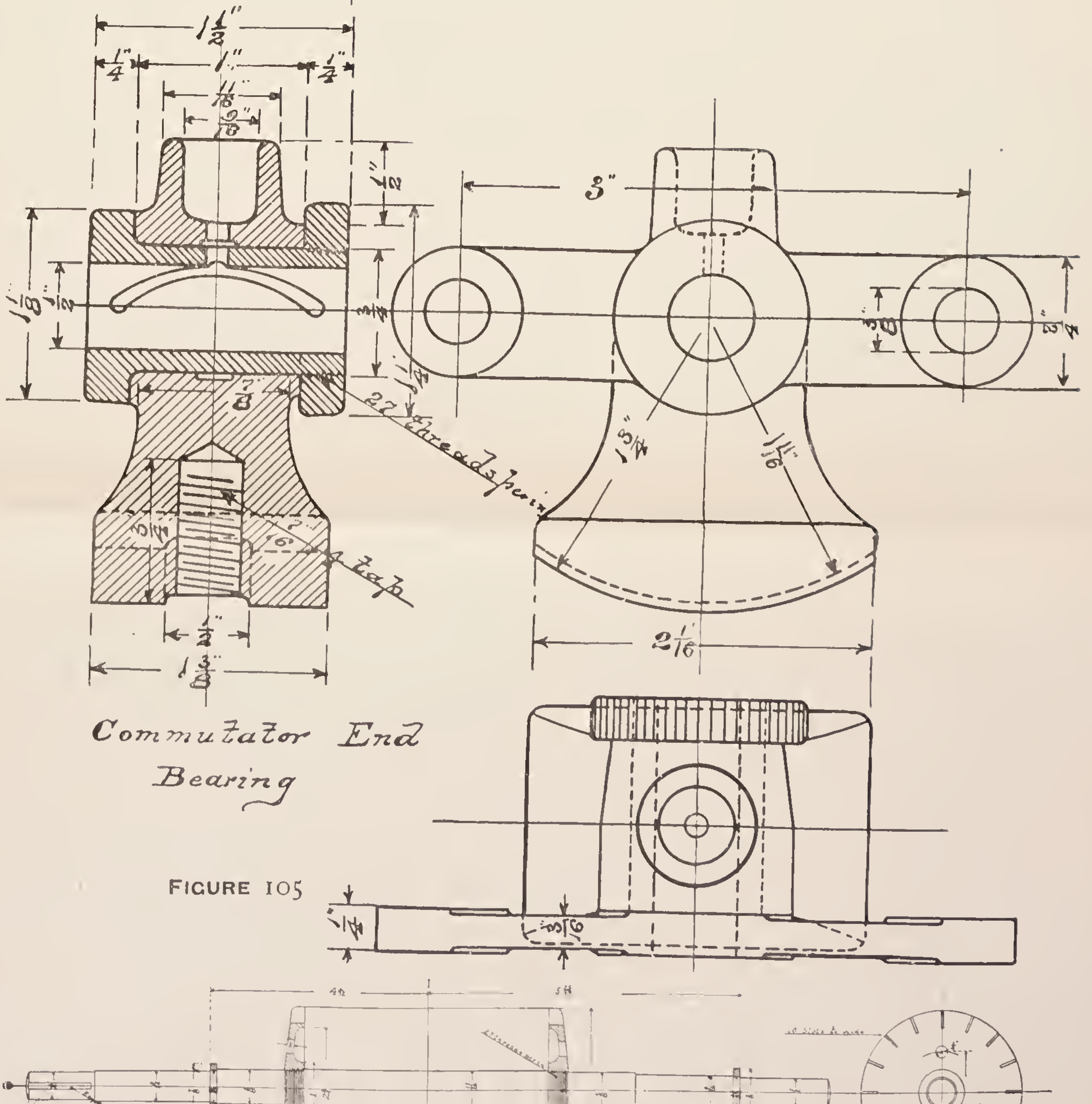


FIGURE 105

FIGURE 106.

frame are for holding the connection board in place. Now put the casting in a fairly large lathe and bolt it securely to the travelling carriage: it may be well to remove the tool post slide from the carriage altogether. With a boring bar between the lathe centers, bore out the fields to the dimensions given.

If the builder has any misgivings about his ability to get the armature winding to its specified dimensions, he may bore the field one thirty-second or one sixteenth of an inch larger; but he must not forget that the greater the air gap between the polar faces and the armature core, the less the output of the machine.

The ends of the arms for the bearings are to be bored out to the same radius as the fields. Let the final chip be a light one with the holding down bolts somewhat relieved, so that the arms may not be sprung any out of line. Aside from the chipping and filing necessary to remove lumps and burrs, the machine work on the fields is now done.

The cast iron pedestals are shown nearly in full size in Figures 104 and 105. They are held on an angle iron on the face plate of a lathe or in a chuck, and the holes for the brass linings bored. Mount them upon arbors and turn off the lower surfaces to the same radius as the field was bored. The brass lining for the pulley end is to be drilled from the solid, mounted upon an arbor and the outside turned to fit tightly in the pedestal. A small brass tube through the bottom of the poll cavity will prevent the lining from working out of position.

It will be noticed that the lining for the commutator end bearing is made integral with the brush holder yoke. This is a unique method of simplifying the mechanical construction. In order to insure oil reaching the shaft, whatever be the posi-

tion of the yoke, a groove should be cut in the iron around the lining as shown in Figure 105. A knurled thumb knot will serve to hold the yoke in any assigned position.

Holes in the bottoms of the pedestals are to be drilled and tapped for the bolts that are to secure them in position on the arms of the frame of the machine. At the pulley end a $1\frac{1}{2}$ inch $\frac{1}{2}$ inch, 13 hexagon headed bolt is to be used, a $1\frac{1}{2}$ inch, $\frac{7}{16}$ inch 14 at the commutator end.

By the construction thus explained and adopted, the builder will see that the bearings will, of themselves, come in line and exactly in the center of the field bore. To take out the armature will require the removal of but one bolt—at the pulley end when the armature with its pulley and bearing can be drawn out lengthwise, leaving the commutator end bearing with yoke and brushes undisturbed.

The armature with the shaft is shown in Figure 106. Cold rolled Bessemer steel is suitable for the shaft. Brass retaining heads screwed on the shaft serve to hold the lamination and winding in place. Sheet iron is the proper material of which to make the core, but it is possible to wind the space full between the heads with fine annealed iron wire, soldering it in several places to the heads to prevent slipping. The layers of sheet iron offer an easy path for the magnetism, while through wire there would have to be a jump from layer to layer.

It will be found well to arrange this part of the work in the following order: If stock for the shaft is of ordinary machine steel, center and turn it to eleven-sixteenths inch its entire length. If cold rolled steel is used, the builder can center it so exactly with the aid of the back rest of the lathe that turning will be unnecessary. From the ends of the shaft

up to the places where the threads are to be cut, reduce the diameter to $\frac{5}{8}$ in.: cut the threads, 27 per inch for $\frac{3}{8}$ in. further. At the bottom of the threads the diameter will be $\frac{5}{8}$ in. The rest of the turning on the shaft should be reserved until the core is built up, as, on account of the variations in the thickness of the sheet iron, the shaft may be sprung or slightly bent.

By referring to Figure 103, it will be seen that the width of the field is $4\frac{1}{2}$ in. The length of the lamination of the armature core should be the same. Wrought iron is commonly used for armature heads and forms a part of the magnetic circuit. In this machine the entire core is sheet iron. Brass retaining heads are used, and these are outside the magnetic path. The castings for these heads are hollowed out somewhat on the inside, for lightness and economy of machine turning. They are to be chucked, turned on the flat side, bored and threaded while in the lathe; or they can be drilled, tapped, mounted on a nut arbor, and then turned. Three $\frac{1}{4}$-in. holes, as shown, are to be drilled in each head. These are for engaging with the pins of a spanner wrench, when screwing the heads on. Sixteen slots, $\frac{3}{64}$-in. wide and $\frac{5}{16}$-in. deep as shown are to be cut in each. These are for holding the winding pegs. This can best be done in a milling machine, but the location for each slot can be marked off carefully, then cut with a hack saw.

Sheet iron .014-in. thick is the standard for armature lamination. Stove-pipe iron is good. The tin-coated iron used in making preserving cans will answer also. The thin layer of tin will not be detrimental. If the builder has difficulty in procuring sheets punched to size, he can buy a sheet of stove-pipe iron and cut it into $3\frac{1}{4}$-in. squares. Clamp the required number

between two metal plates and drill a $\frac{11}{16}$-in. hole through the whole mass. Mount upon an arbor, (do not use the shaft for this purpose), and clamp them together by means of nuts threaded upon the arbor itself. Turn to $3\frac{1}{16}$-in. diameter; there will be a saving of time in turning if the sheets have their corners clipped beforehand.

Screw one head on the shaft very tightly, and slide on the punchings until there is just room only to catch the threads of the other head. Screw this to its right position and ascertain if the sheets are tightly pressed together; if there is room to get a knife in, remove the head and slip on a few more sheets. The shaft can now be put on the lathe, and the core carefully turned to its final diameter—3 inches. Finish the brass heads on the outside and turn the shaft itself to the dimensions shown for the commutator, bearings and pulley. Steel shoulder rings are to be forced on as shown, in order to receive the end thrust of the armature when running.

At the pulley the diameter of the shaft is $\frac{1}{2}$ inch; at the bearing $\frac{9}{16}$ inch; for the shoulder ring $\frac{19}{32}$ inch; then to the head it is $\frac{5}{8}$ inch. Beside the other head the diameter is $\frac{5}{8}$ inch again, then $\frac{9}{16}$ inch for the commutator, $\frac{17}{32}$ inch for the shoulder ring, and $\frac{1}{2}$ inch at the bearing. The rings are $\frac{7}{8}$ inch diameter and $\frac{1}{8}$ inch thick.

No pulley is detailed, but one 3 inches in diameter, with $1\frac{3}{4}$ inch face, for $1\frac{1}{2}$ inch belt, will answer for a motor. For some purposes, as for driving a boat, for which the motor may be used, a pinion $1\frac{1}{2}$ inches pitch diameter, 1 inch face, 18 teeth, can be keyed on the shaft. The gear into which the pinion meshes is to be mounted on the propeller shaft, and a bearing can be screwed on to the bottom of the field casting.

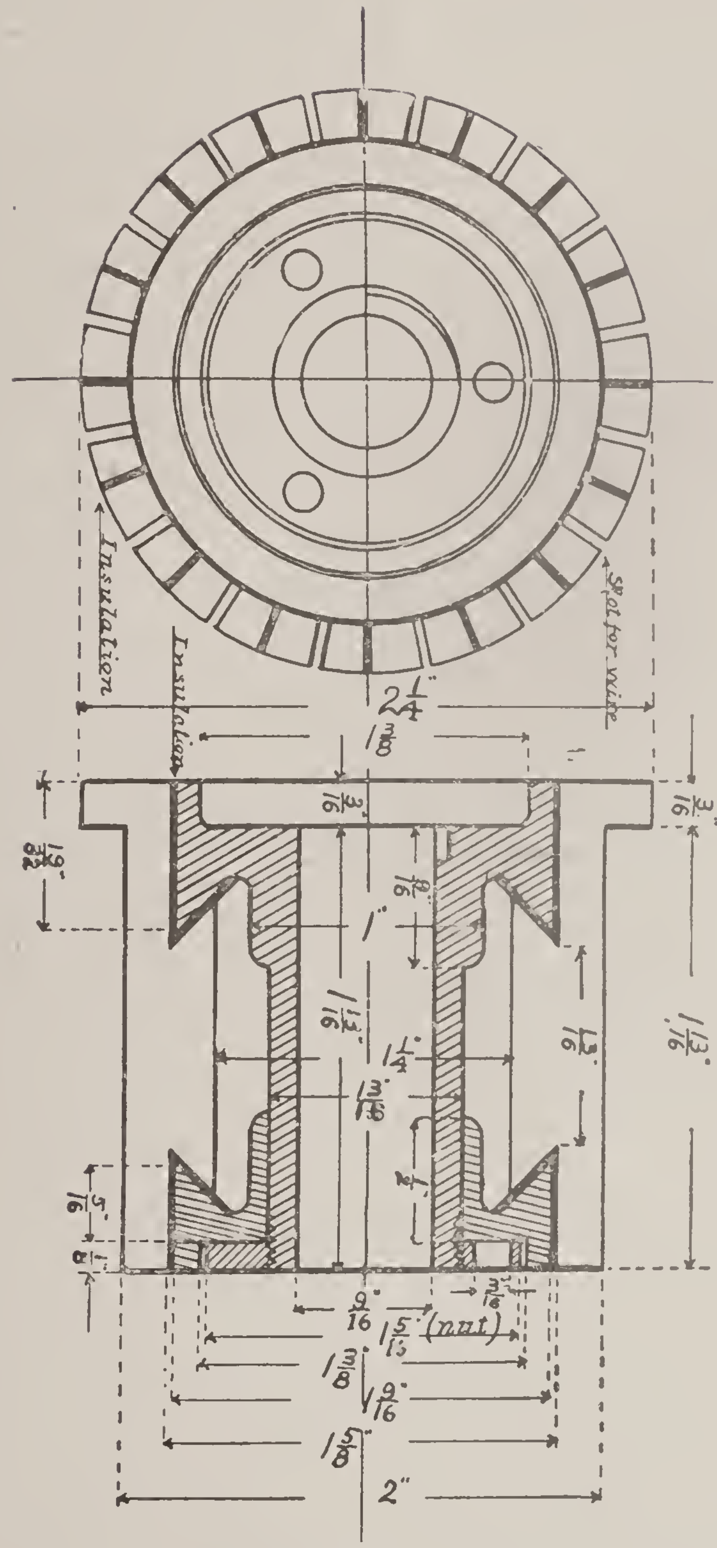


FIGURE 107.

Belting should be used wherever possible, as any other device wears out the bearings faster and makes more noise. If the machine is used as a dynamo it will be well to make the pulley 4 inches in diameter.

The construction of a commutator, more than any other one part of a dynamo, is a Waterloo to amateurs. There is no part requiring better work. Its character directly affects the sparking element of the machine; it is the only expensive part that receives serious wear. It must be very securely made to resist the centrifugal force when revolving. The writer has given up the attempt to get a cheap and durable commutator in one. The remedy was to describe two different commutators, and let the builder make that one which suits his tools and inclination.

The commutator to be first described is the better one. It is shown finished in Figure 107. The sectional view represents a "sleeve" with flange at back end. This sleeve is bored out $\frac{9}{16}$ inch to fit the shaft. A notch, as shown, is to slip over a pin set in the shaft, to act as a key for preventing the commutator from slipping. The back flange is turned conical at its upper inner edge, and corresponds in shape to the "cap" at the other end of the sleeve. A nut threaded on the sleeve holds the parts together. These conical surfaces grip the segments and hold them securely in position. Either of two methods may be observed for making the segments, 16 in number. A copper casting in the form of a ring may be procured and turned to the dimensions shown in Figure 108. It can then be mounted upon an arbor and placed on centers in a milling machine. With a saw $\frac{1}{32}$ inch thick, on the mandrel cut the castings longitudinally almost through into 16 parts. Leave about $\frac{1}{32}$ inch of stock at the bottom of the cuts. If a milling machine is not available

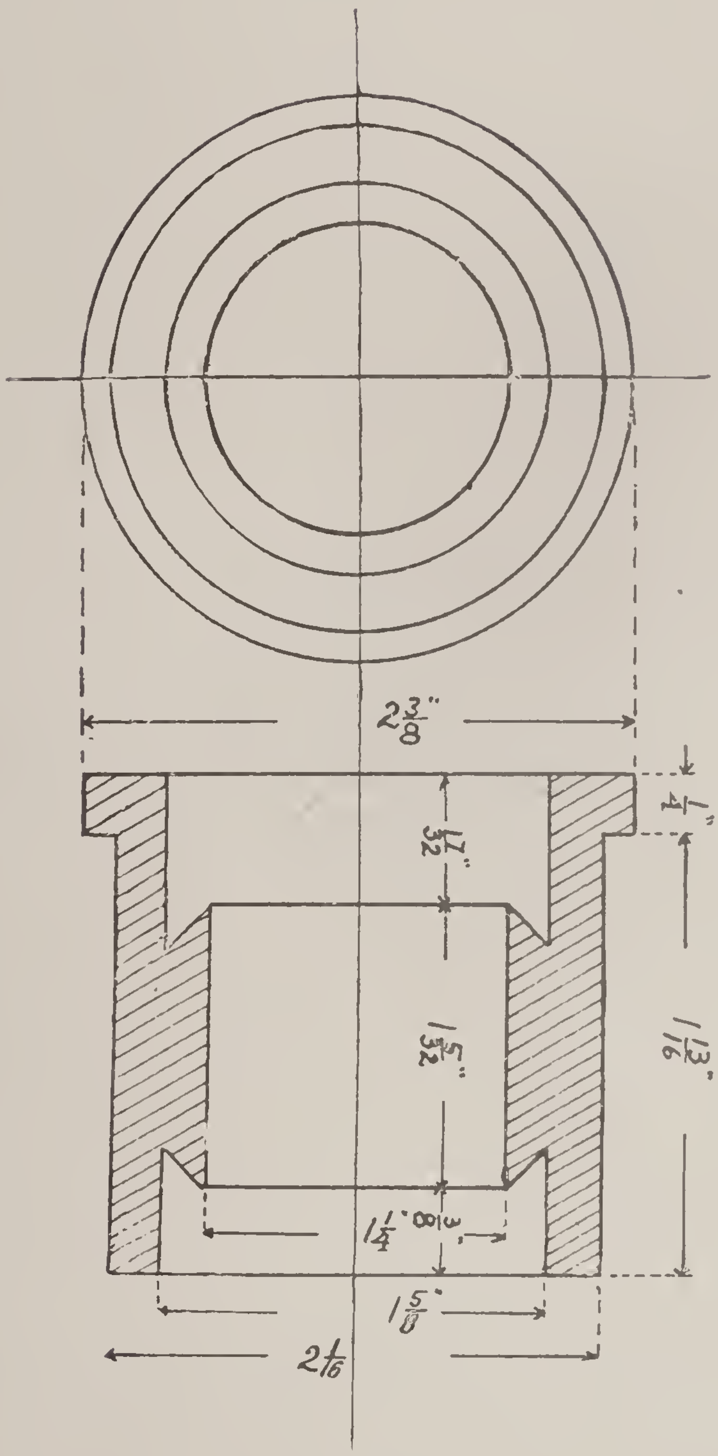


FIGURE 108.

mark off the location of the cuts in this manner:—Take a piece of drawing paper $1\frac{3}{16}$ inches wide and long enough to wrap around the ring exactly. Lay the strip flat, divide it with a pencil into 16 equal parts. Stick this on the ring with shellac, wind string around it and wait a day until it is perfectly dry and hard. Remove the string and with a hack saw proceed to saw exactly on the pencil lines until each of the 16 cuts are almost through the ring. The rim around one edge of the ring is to allow for connecting with the armature winding. Half-way between the division slots cut additional slots through the rim down to the surface of the ring; the wires are to be soldered in these slots.

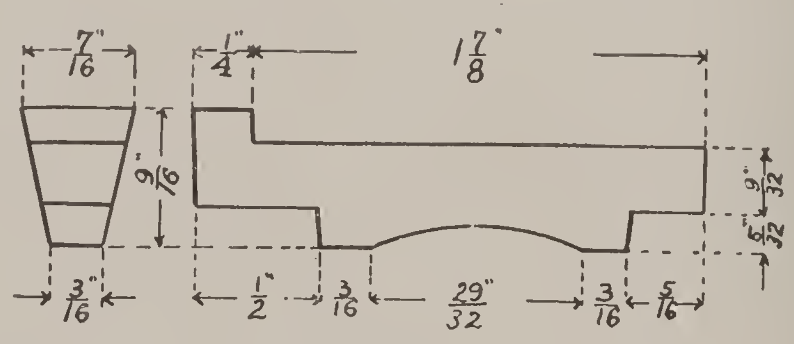


FIGURE 109.

Fit mica or vulcanized sheet fibre to the division slots and make this insulation conform to the shape of the inside ring. Fit conical rings of shellacked paper $\frac{1}{32}$ inch thick to the tapering surfaces. Now cut the segments entirely apart and then set them up separated each from the other by the insulation. Put the flanged sleeve through, slide on the cap, and screw up the nut by means of a spanner wrench. The commutator can then be laid aside until the armature is wound.

The other method of preparing the segments is to have them cast separately in the first place. Such an unfinished casting is shown in Figure 109. A metal pattern, with the angle pretty

exact, should be made. The 16 castings should be filed until they will set up tightly into a complete circle. Shellac a small piece of drawing paper on both sides of each segment flush with the lower edge. After these are dry, shellac the outside of the papers and set the segments up in a circle around an arbor. A short piece of steam pipe should have been previously prepared with 32 set screws, two for each segment. This is slipped

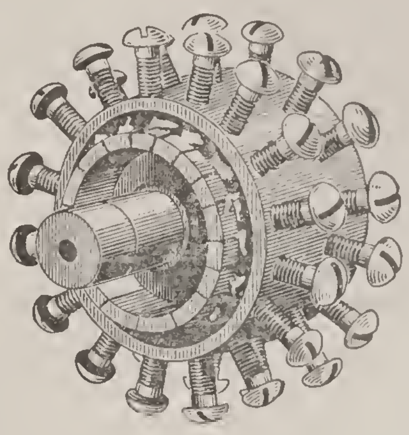


FIGURE 110.

over the whole and squeezed together by means of the screws. The arbor in the center compels them to be kept in a circle. If any looseness shows itself between the segments, more insulation should be placed between them. Make sure that the segments are very tightly pressed together. Yet the arbor must also be held tightly to allow for the lathe work. The central portion only of the arbor, where the segments touch, will be about $1\frac{1}{4}$ inches in diameter. Each side of that the diameter

should be $\frac{5}{8}$ inch to allow for reaching the segments with the turning tool. (See Figure 110.)

Turn out the conical surfaces as shown in Figure 108. Carefully drive out the $1\frac{1}{4}$ inch arbor. Insert the conical paper insulations, put in the sleeve cap and screw up the nut. Loosen the set screws, remove the piece of pipe. Mount the commutator upon a $\frac{9}{16}$ inch arbor and turn the outside smooth. Saw the slots for the wire connections. This latter method is the principle of construction adopted by manufacturers of standard dynamos and motors.

To make the simple commutator shown in Figure 111, the builder must get a block of vulcanized fibre about 2 inches long and $2\frac{3}{4}$ inches in diameter. Drill a $\frac{9}{16}$ inch hole through the center and turn the outside down true. In one end turn a circle $1\frac{7}{8}$ inches in diameter, only deep enough to serve as a mark. Divide this circle into 16 equal parts and prick-punch each. Drill lengthwise through the block with a small drill at each of these spots, and finish with a drill $\frac{5}{16}$ inch in diameter. (It will be best to make a steel templet with 16 holes, besides the $\frac{9}{16}$ inch center hole. Clamp this on the block and drill according to the templet. There will then be no chance of the drill running out of line). The holes, when finished, should have less than $\frac{1}{16}$ inch of stock between them. It will be necessary to put a brass or steel rim on each end of the block, as shown, in order to ensure the block from cracking. Brass or copper rods $2\frac{1}{8}$ inches long are to be driven into the holes, letting one end come flush with the block. Slot the protruding ends radially with a hack saw for the wire connections. Now mount in a lathe, finish the ends smooth and turn down, between the rings, through the fiber, to 2 inches in diameter. Each rod will then

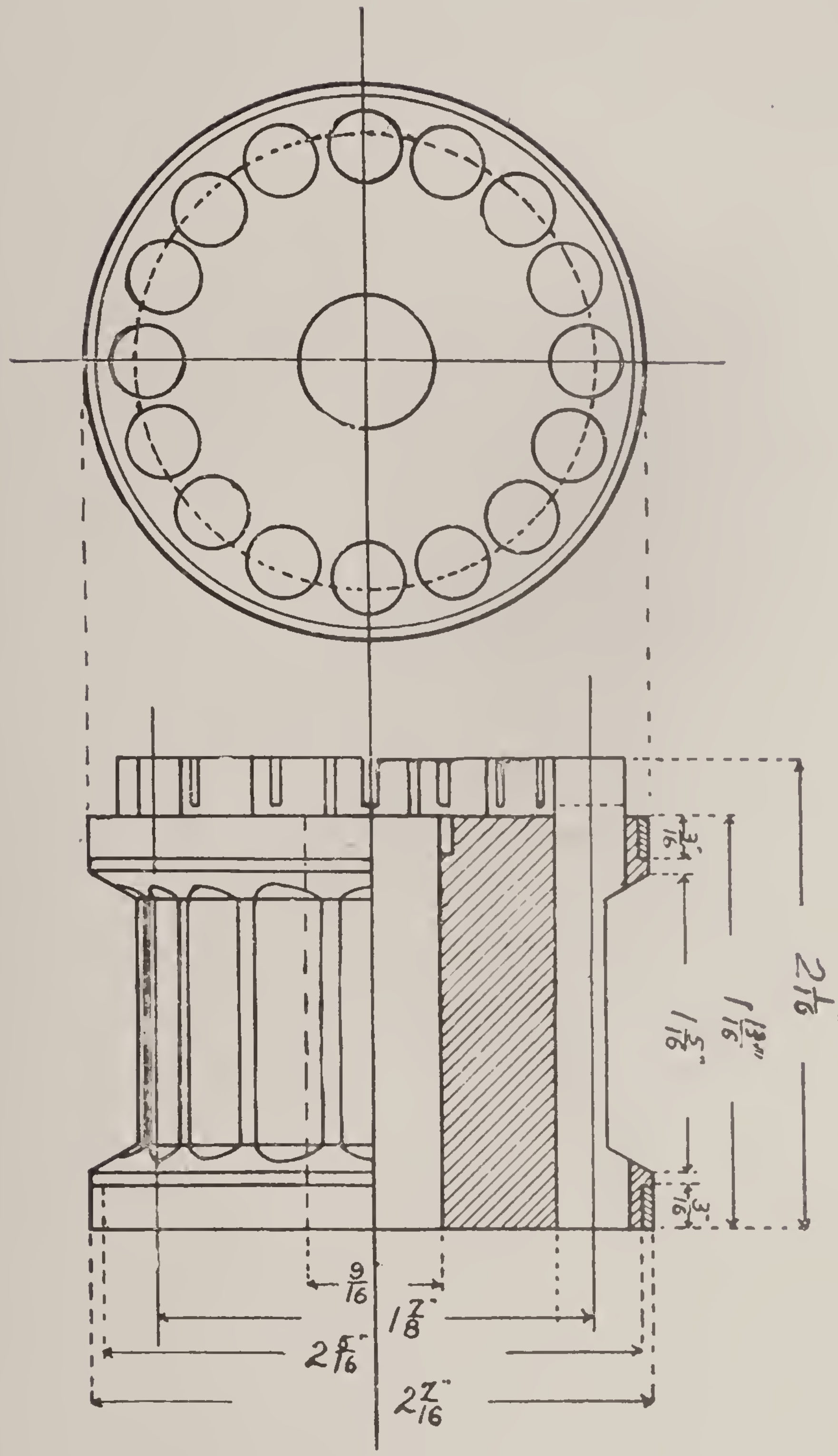


FIGURE 111.

present a circular face insulated from all the others and contribute towards making a serviceable commutator. As the commutator wears the segments will seem to get closer to each other until the diameter reduces to $1\frac{7}{8}$ inches, then as a center line of the rods is passed the thickness of insulation will increase.

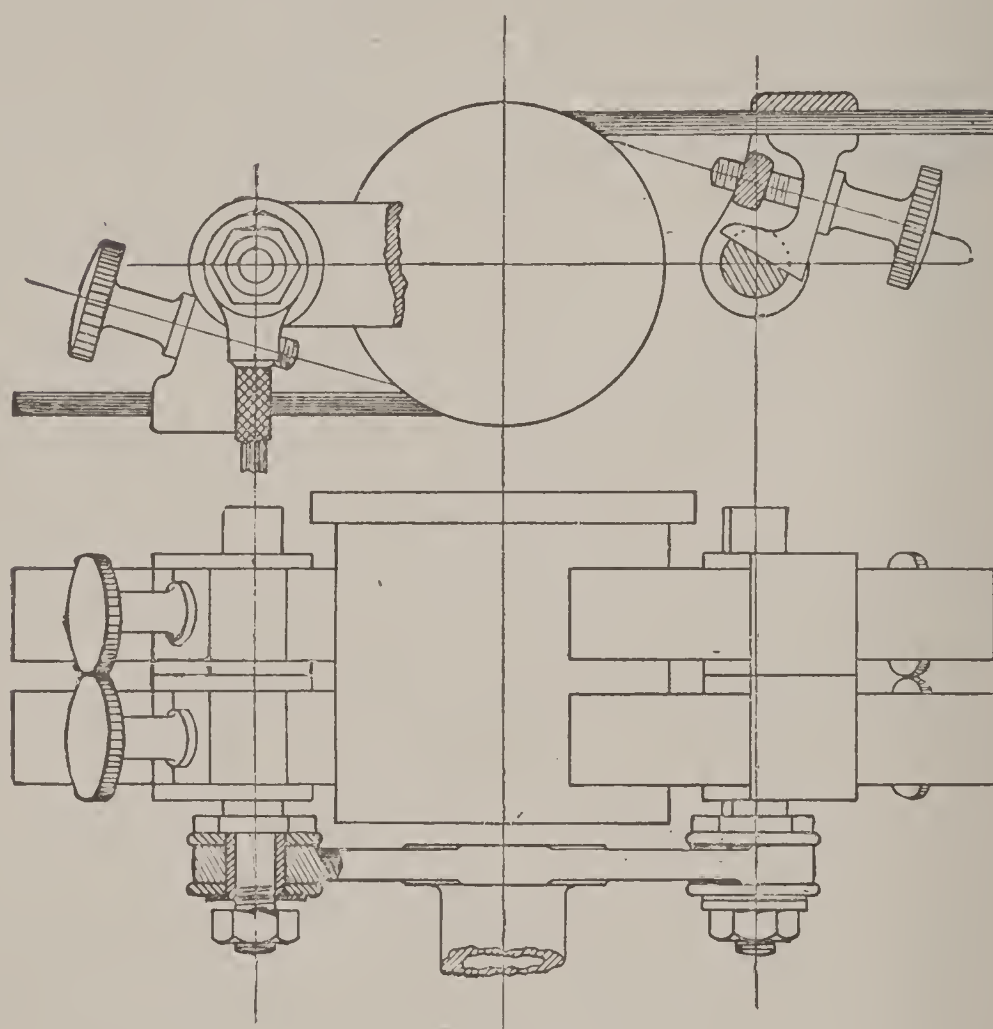


FIGURE 112.

When the diameter has worn to $1\frac{3}{4}$ inches probably the brushes will spark disastrously.

The brush holder yoke has already been made, as it is a part of the commutator end lining, so the brush holders, brushes, studs, and insulations are in order. These parts are shown assembled in Figure 112. Each brush holder consists of three

parts, shown detailed in Figure 113. The body and shoe are brass castings, while the thumb-screws are made of brass rod. The parts can be bright finished all over or left rough as the builder chooses. The brushes themselves are of leaf copper .005

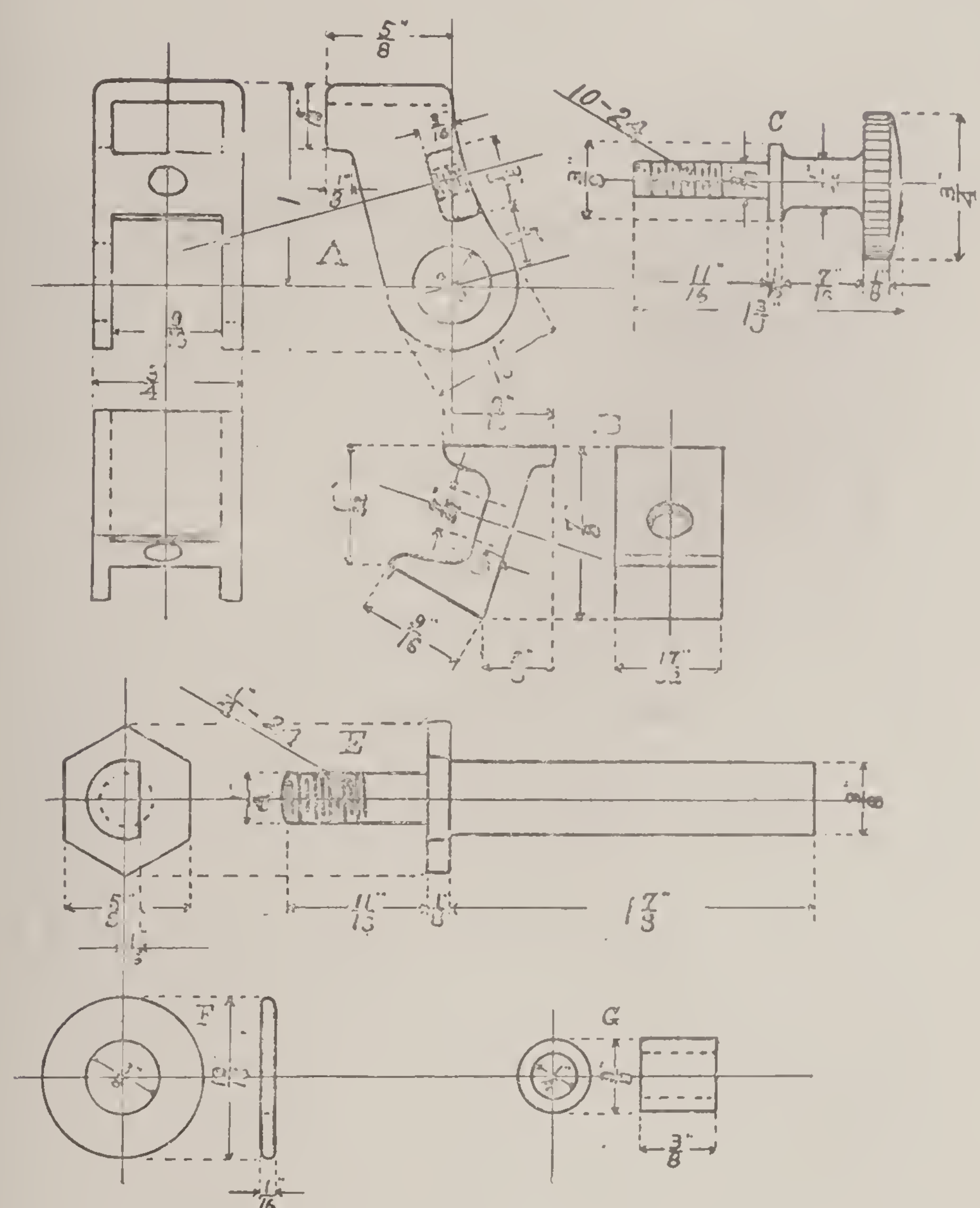


FIGURE 113.

inch thick, laid layer upon layer until a thickness of $\frac{1}{8}$ inch is reached. Then a thicker sheet, say .015 inch, is laid on top. The whole mass is to be soldered together at one end, the other beveled, as shown, to fit the commutator. If the commutator

first described is built, four brushes can be used, two on each side. Only two brushes can be used, one on each side, with the commutator last described.

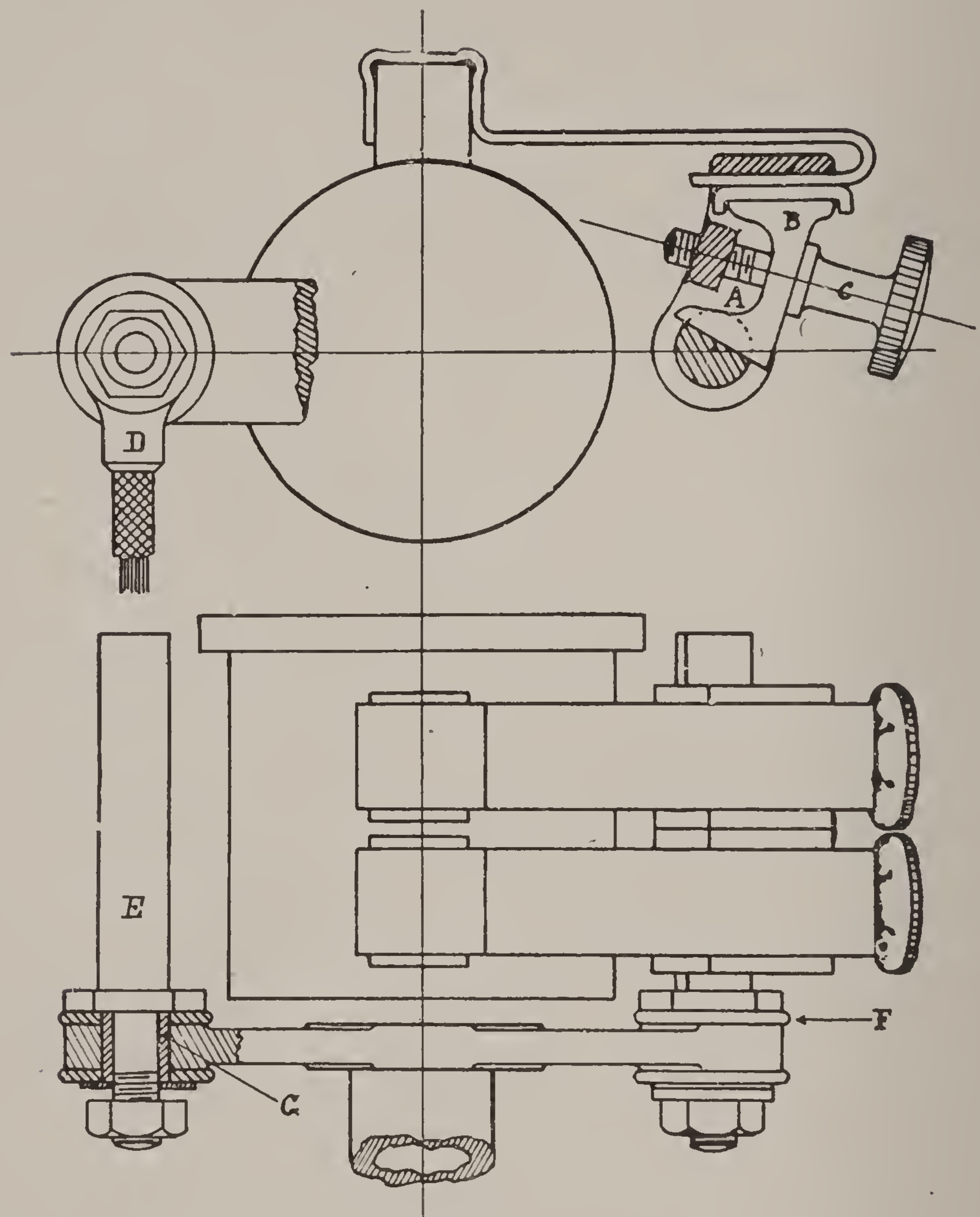


FIGURE 114.

In Figure 113 the studs and insulations are shown. Two studs are to be made; $\frac{5}{8}$ inch hexagon brass rod can be turned to the dimensions given, or $\frac{3}{8}$ inch round rod can be used by driving on hexagon washers to serve as shoulders. The washers

should be driven on over the end that is reduced to $\frac{1}{4}$ inch diameter, soldered, and turned off true. The studs are filed flat on one side. By means of the thumb-screw the shoe is wedged tightly between the brush holder body and the stud, thus holding the brush and brush holder in position. More or less pressure of the brushes upon the commutator can be obtained by turning the stud by means of a fork wrench upon the hexagon shoulder. The bushings and washers for insulating the studs are of hard rubber. Brass washers should also be inserted between the nuts and the rubber.

For reversible motors, carbon brushes will be necessary. These are shown assembled in Figure 114, details are given in Figure 113. For each holder a strip of copper $\frac{1}{16}$ inch thick is to be bent as shown and a block of soft carbon inserted in the jaw. Immerse the carbon and end of strip in a solution of blue vitriol, and, with a battery, plate with copper until the carbon is covered and well joined to the strip. With a piece of emery cloth on a round stick hollow out the carbons, so that they will fit the commutator.

Maple is suitable material for the connection board. If the machine is intended as a series motor or dynamo, the arrangement shown in Figure 115 is to be used. Binding posts for circuit wires are in the two upper corners. Terminals from the brush holder cables enter the other two corners. The current, coming in on one side, enters a long brass strip, from which it passes to the field coils by wires as shown, back to the other strip and out to the rest of the circuit. On the other end of the board there is simply a straight connection from cable to binding post.

For a shunt motor or dynamo the board shown in Figure

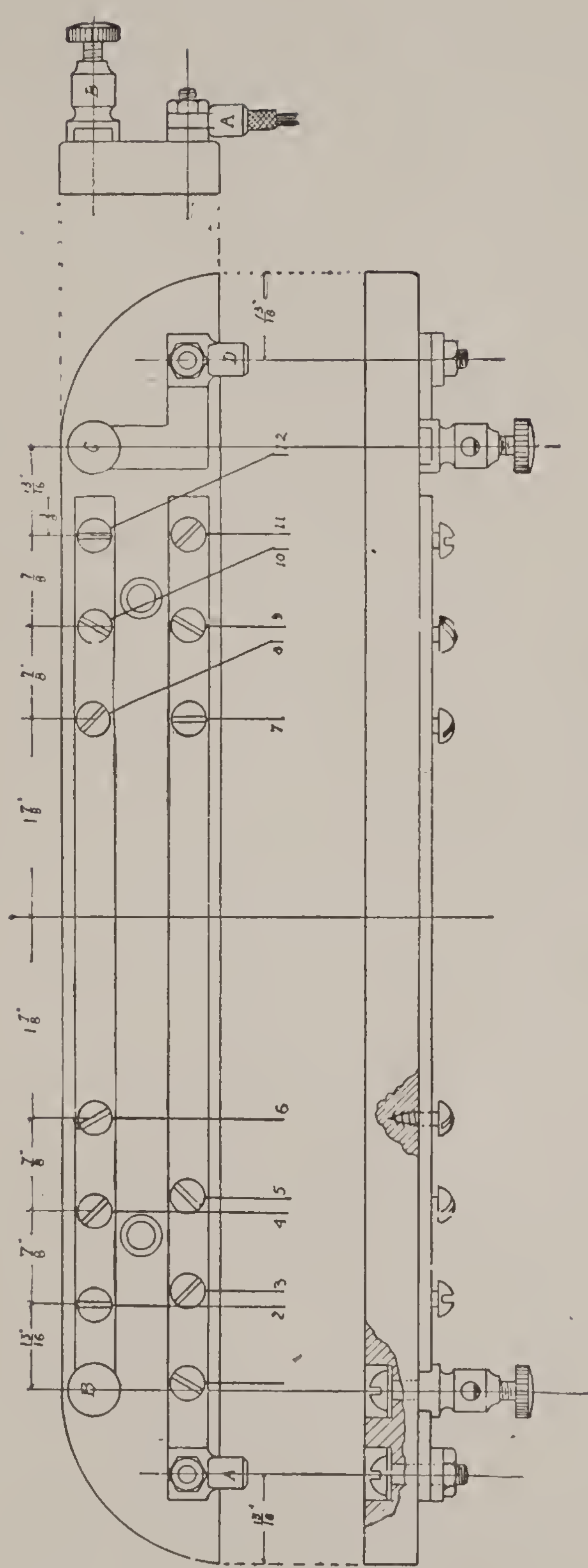


FIGURE 115.

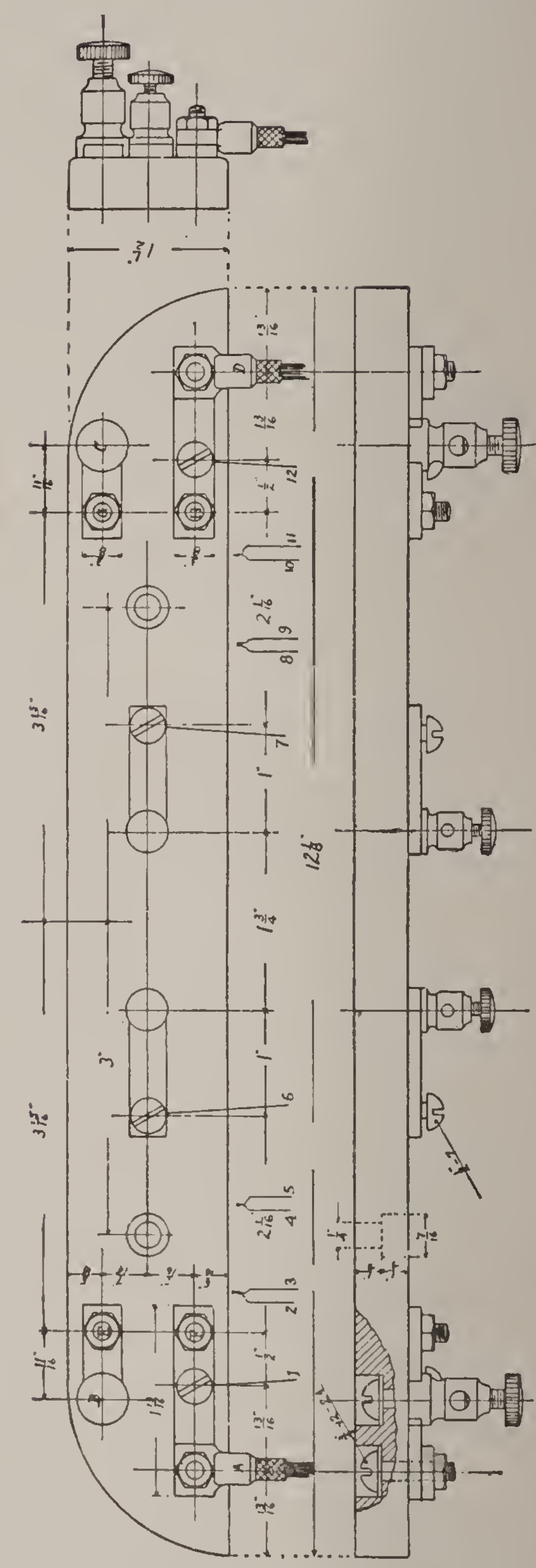


FIGURE 116.

116 is to be used. It will be seen that there is a straight connection through the fuses from cables to binding posts at each end. The field wires are connected in series with each other and shunted across the terminals. If the machine is used as a motor the two binding posts, Nos. 1 and 3, are to be connected by a straight wire; if as a dynamo these binding posts offer connections for a rheostat for varying the potential. This is usually necessary to compensate for variations in speed and load.

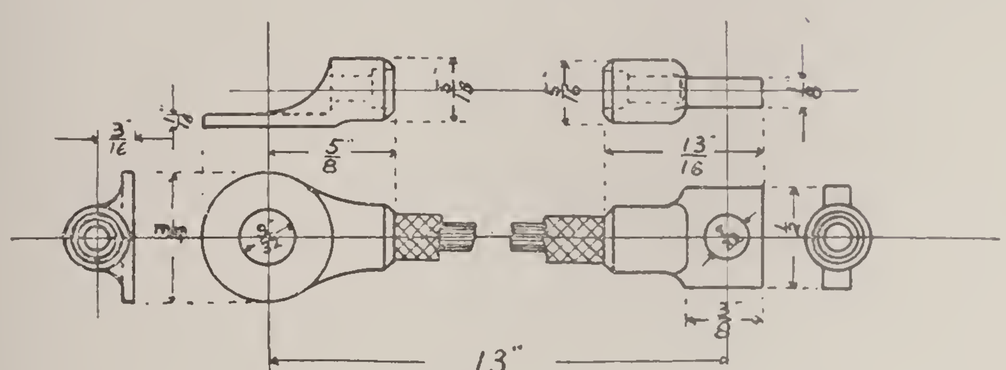


FIGURE 117.

Two $\frac{3}{4}$ inch—14—20 fillister head brass screws will serve to hold the connection board in place on the field magnet. Flexible cables to connect the brush holders with the terminals on the board are necessary.

Incandescent lamp cord will answer if the double strand is used on each side of the machine. A single strand will not be quite sufficient to carry the current. The length necessary and the tips are shown in Figure 117.

The tips shown are small brass castings, but sheet copper $\frac{1}{32}$ inch thick can be used. By curling one end of a short strip a suitable receptacle for the cable will be given. It is well for the insulation to enter the tips for an eighth of an inch. This prevents unraveling, also supports the wires of the cable so that they are not easily broken.

Insulate the armature for winding. Wrap around the shaft four thicknesses of thin paper and two of cloth, well shellacked. Let this extend from close to the heads for about an inch and a half along the shaft. Shellac a disc of thin paper over each of the brass heads; let the paper be large enough in diameter to lap over on to the cylindrical surface of the core; split the edges of the paper to make it lie flat. Wrap one layer of paper around the core itself, but this strip should be wide enough only to cover what was not reached by the overlapping paper discs. Put on a second layer that laps over on to the heads. Put small discs of paper over the heads to reach this. A layer of common white cotton cloth can be shellacked on, still observing the principle of breaking the joints.

Under no circumstances should a joint come on the edge of the heads. An outside layer of paper completes the insulation. The diameter of the core over insulation should not exceed $3\frac{1}{16}$ inches. With a needle feel along the edges of the core until the slots in the heads are found. Cut through the insulation with the point of a jack-knife blade. Drive into each slot a strip of leatheroid or fiber $\frac{3}{64}$ inch thick, $\frac{5}{16}$ inch wide, and leave them sticking out about $\frac{5}{16}$ inch.

The insulation and winding of the armature can well be carried on by supporting it between lathe centers. A more convenient and simple support is shown in Figure 118. It is made of wood and its construction is too plain to need description. The ends of the armature shaft rest in the semi-circular notches.

Everything has now been described except the winding itself. The builder must determine what sizes of wire shall be used, by the purpose for which the machine is built. If it is to be used as a motor on a constant potential, or incandescent lamp

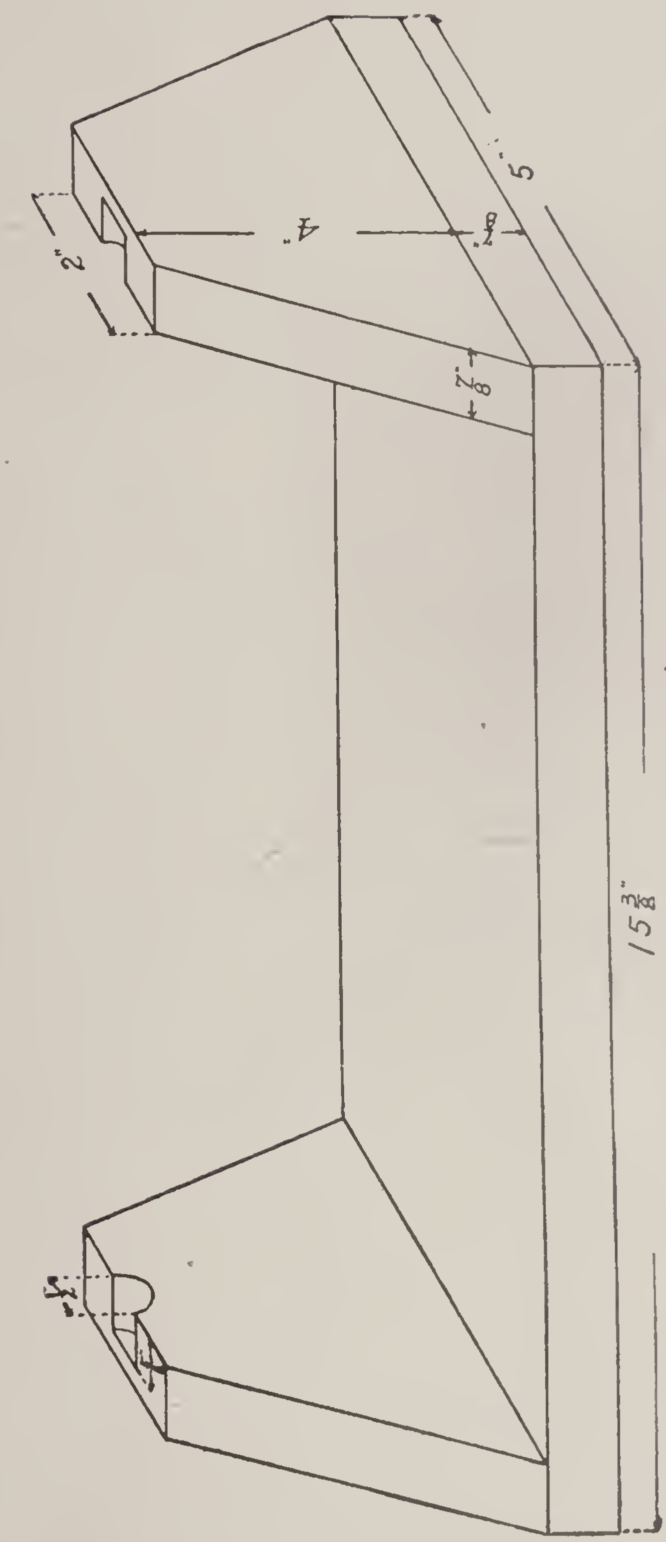


FIGURE 118.

circuit of 110 volts, certain sizes of wire should be used. If as a series motor on constant current or arc circuit of 10 amperes, other sizes should be used.

Other conditions will necessitate something still different. The method of winding will be the same in all. For purposes of description the following has been selected:

Winding adapted for series motor for 10-ampere arc circuits, or with battery power for running a boat or lathe and few other tools; or as a dynamo for running one full arc lamp or 10 16-c. p. incandescent lamps.

This winding will be for 52 volts potential at the brushes. A current of 13 amperes can safely be allowed. No. 16 (B & S.) gauge double cotton covered wire is to be used. Place the armature core in its support and with the spool of wire conveniently arranged, bend the end of the wire so as to hook around one of the pegs. It may be tied to the peg if need be. With one hand carry the wire along the surface, in between two pegs at the other end of the core. With the other hand turn the core one-half a revolution, so the wire will be laid across the end between the two pegs directly opposite. Do not pull it tightly against the shaft, but let there be a space of about $\frac{1}{4}$ inch. Bend the wire over the edge and back along the core to the other head, then with another half turn of the core backward return to the starting point. The same space should be allowed between the wire and the shaft as on the other end; keep on with the wire alongside the first turn until another is placed. The space between the wire where it crosses the heads and the shaft will be getting less with each successive turn until five turns are placed. The last turn should wedge in tightly. Pass the next turns on the other side of the shaft. The winder

will find that he must rotate the core the other way as each successive half turn is placed. Let these turns be close to the

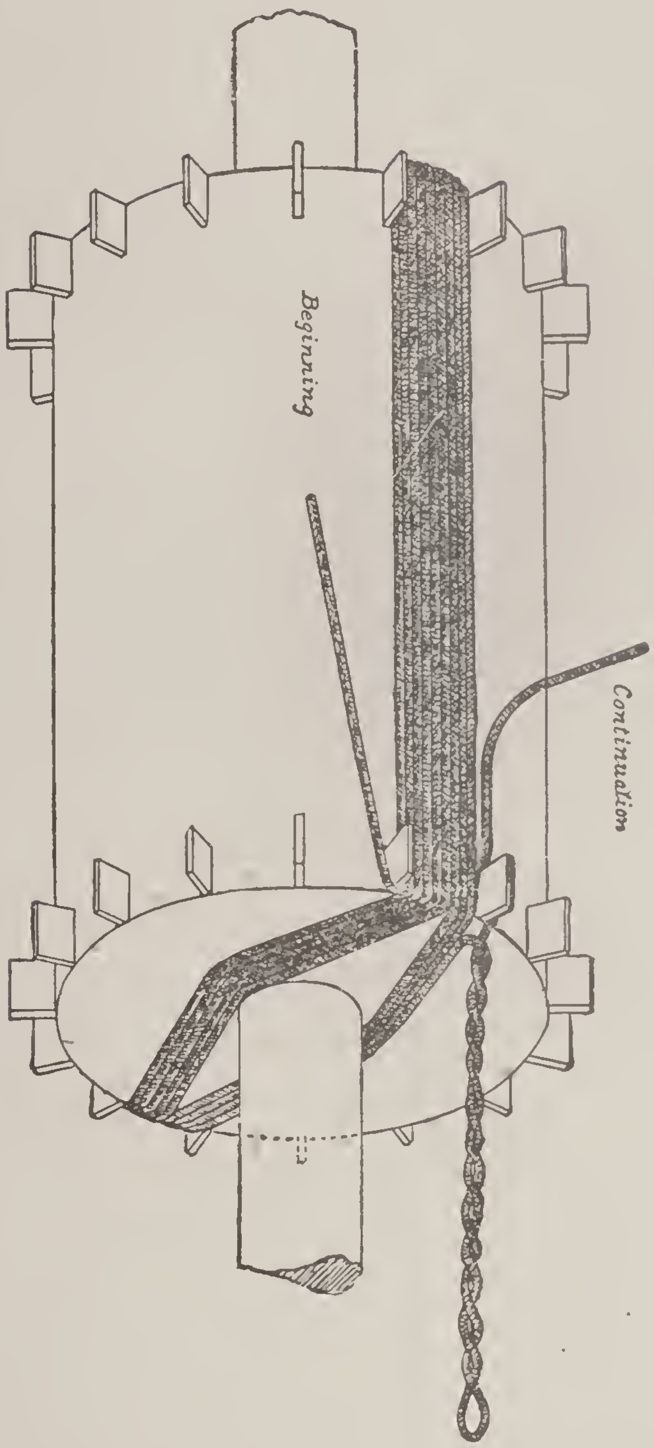


FIGURE 119.

first wires but tight against the shaft. There will be room for only four turns on this side of the shaft. Do not cut the wire

when the entire space between the pegs is filled but make a loop about 3 inches long, twisting it together until the continuation of the wire points straight across the head. Figure 119 shows the first coil all wound, also where the beginning and end is. Lead the wire into the space alongside the first coil. To do this, it will of course be necessary to cross the first coil diagonally. Be sure to let there be kept a distance of $\frac{1}{4}$ inch from the shaft as before, so as to leave room for the following turns. Put on the five turns on that side of the shaft, then four on the other side and the second coil will be wound. Bring out a loop, twist it together as before, and proceed to cover the space between the next pegs. Pull the wire tightly when possible and always straighten it carefully with the fingers as each turn is laid on. The same order is to be observed for winding eight coils. There will then be eight loops left out for connection with commutator segments. However, there are sixteen segments. How are connections for these to be provided for? For a ninth coil start a turn of wire directly on top of the one wound at the very beginning. Put a complete layer on as if there were no winding already there. It will be noticed that on that side of the shaft where in the first layer there were only four turns, five will appear in the second layer, and four in the second on top of the five of the first layer. So the winding is balanced. The second layer over the entire surface will make eight more loops for connections. No cut is to be made in the wire at any time, until the winding is completed, when the last and first ends are to be twisted together. Thus the armature circuit is one continuous winding, with connections allowable at 16 different places. Shellac the whole very thoroughly. Figure 120 shows the armature at this stage of

construction. Cut off the extra insulation on the shaft beyond the winding and slip the commutator in place.

If the machine is to be used for general purposes as dynamo or motor, and running in either direction, the loops from the armature winding should be led straight to the nearest segments. Scrape the insulation from the wires where they enter the slots in the commutator and solder each carefully. Both wires comprising a loop are to be soldered to the same segment,

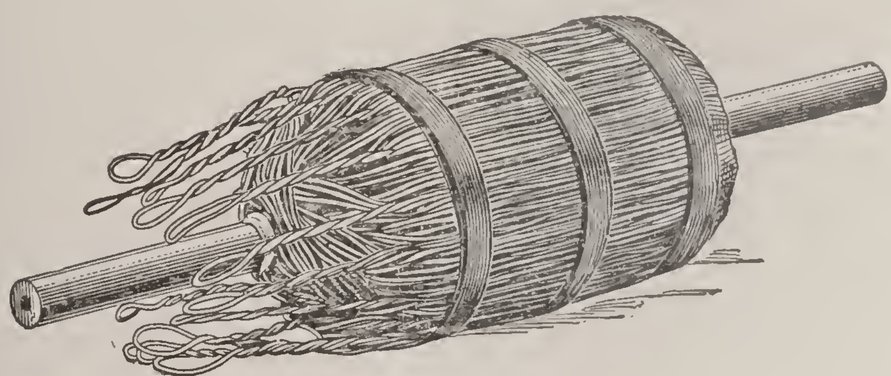


FIGURE 120.

and the superfluous ends cut off. It will be seen that the end of one coil and the beginning of the next is unbroken.

With the connections made straight like this, the position of the brush holders and yoke, when the armature is running, will be about horizontal, provided carbon brushes are used. With copper brushes the yoke must be tilted to an angle of 45°. It will be possible to allow the yoke to be horizontal, simply for looks, by giving the connection wires from the armature to the commutator a "lead." Instead of connecting a given loop with the nearest segment, carry it to the second segment to the right or left, depending on which direction the machine is to run. The other loops follow in order, giving the appearance that the commutator had been twisted out of position one-eighth of a turn.

"Binding" wires will be necessary to hold the copper conducting wires in place. Around each end of the core next to the protruding pegs and in the middle, wrap two turns of thin drawing paper, well shellacked. Mount the armature in a lathe, and with the back gears in use wind tightly No. 25 German silver or brass wire on over the paper bands. The beginning of the wire can be secured to an armature lead wire. After one band has been covered make a quick reach to the next without cutting the wire. Solder the binding wires very securely together. There is no objection to soldering them all the way around. Resin should be used as a flux in soldering electrical work, as acid is apt to rust the joints.

The lead wires to the commutator can be covered with a conical sleeve of duck, well shellacked. Bind the cloth in position by winding strong linen thread around it where it laps on to the armature and commutator.

Clean the shaft from all shellac, slip on the pulley end bearing, put on the pulley, drive in the key, and the armature awaits the field winding.

An armature winding has been selected and described best fitted for general work. The field can also be made to accommodate itself to several conditions. The coils are to be wound in sections, slipped on to the pole pieces, and then connected in multiple or series according to the particular application.

The builder has a choice of the size of wire he may use. The amount of energy absorbed in the field is a large factor in determining the commercial efficiency of the machine.

To excite the field sufficiently to generate 52 volts requires about 5000 ampere turns. This can be accomplished with a total of 2200 turns of No. 18 wire, and for a shunt machine allow-

ing $2\frac{1}{4}$ amperes of current to flow. On each field core are three separate coils all connected in series. On the connection boards the ends of the six coils are shown by figures; the odd numbers indicate the outside ends, while the even numbers refer to the inside ends. Figure 116 for the shunt connection board shows the coils connected in series with each other. Figure 115 for the series board shows them connected in multiple, making the total resistance of the field $\frac{1}{36}$ as much as in the other case.

Figure 121 shows the "form" to be used for winding the field coils. It is made of maple and bolted to the face plate of a lathe. Wrap two thicknesses of thin brown paper strips around the center piece.

Do not shellac it but begin winding the wire tightly; let the end of the wire be held in a hole through one of the side blocks. It is well to run the lathe slowly, even to use the back gears. A thin maple strip held in one hand is convenient to crowd the wire into position. As each layer is put on it should be shellacked and one thickness of thin brown paper laid on and again shellacked. The paper will make the layers even and with the shellac bind the whole so together that it may be removed from the form without injury. Hammer the wire to keep it from bulging up in the center. With the best of precautions, however, it will measure more across the middle than at the ends. About 23 layers should be put on, with 16 turns per layer.

The bolts which hold the form to the lathe also hold the parts of the form together, so it is an easy matter to take off the side pieces when a coil is wound. The center block can be driven out as the unshellacked paper that was put around it in the beginning will allow sufficient slipping.

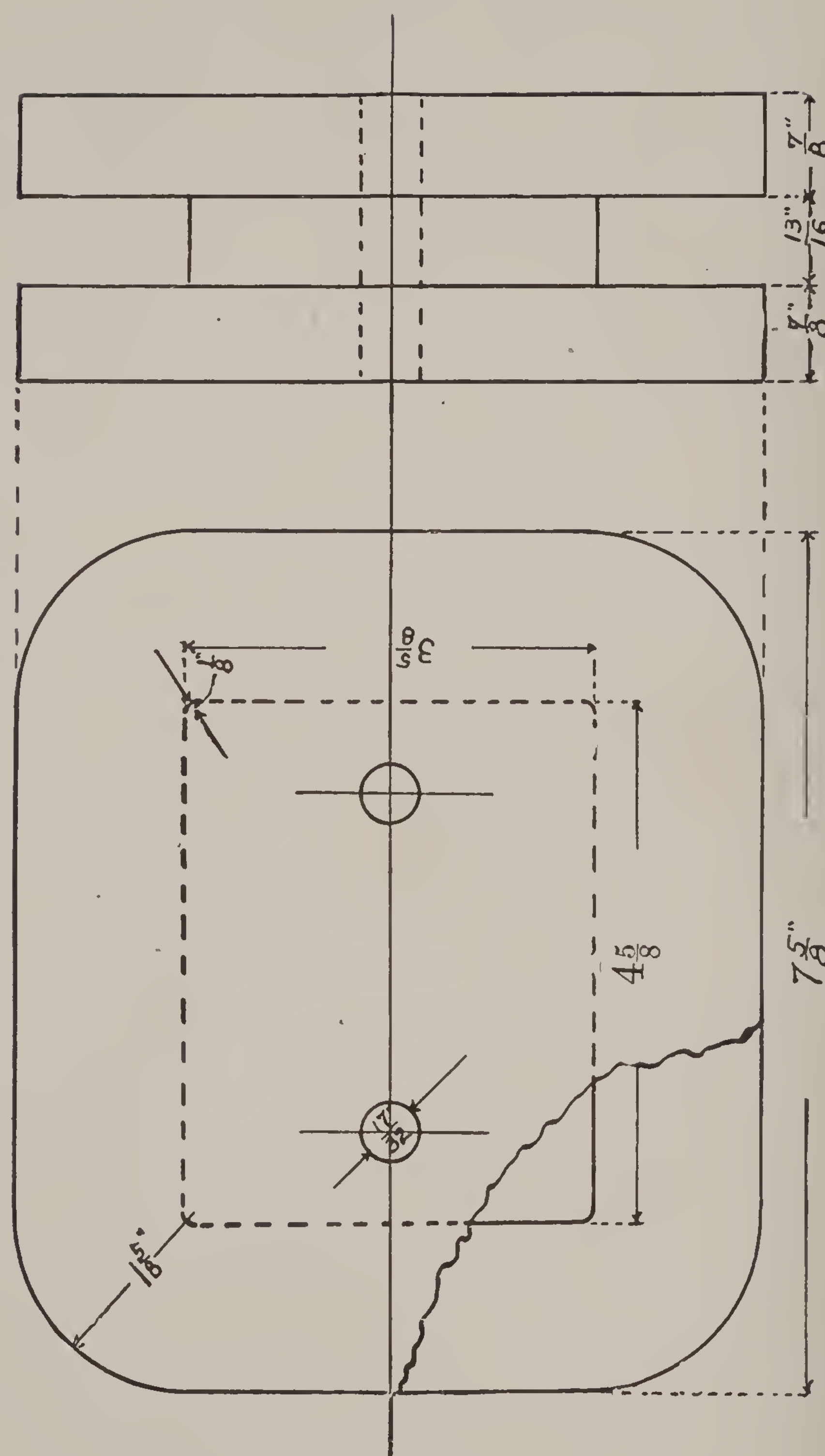


FIGURE 121.

The ends of the coil should be wound with a little thin paper and the whole coil bound together by wrapping cotton tape all about it. Each coil will weigh about $3\frac{3}{4}$ pounds.

A complete coil is shown in Figure 122. Paper should be wound on the pole pieces before slipping the coils in place

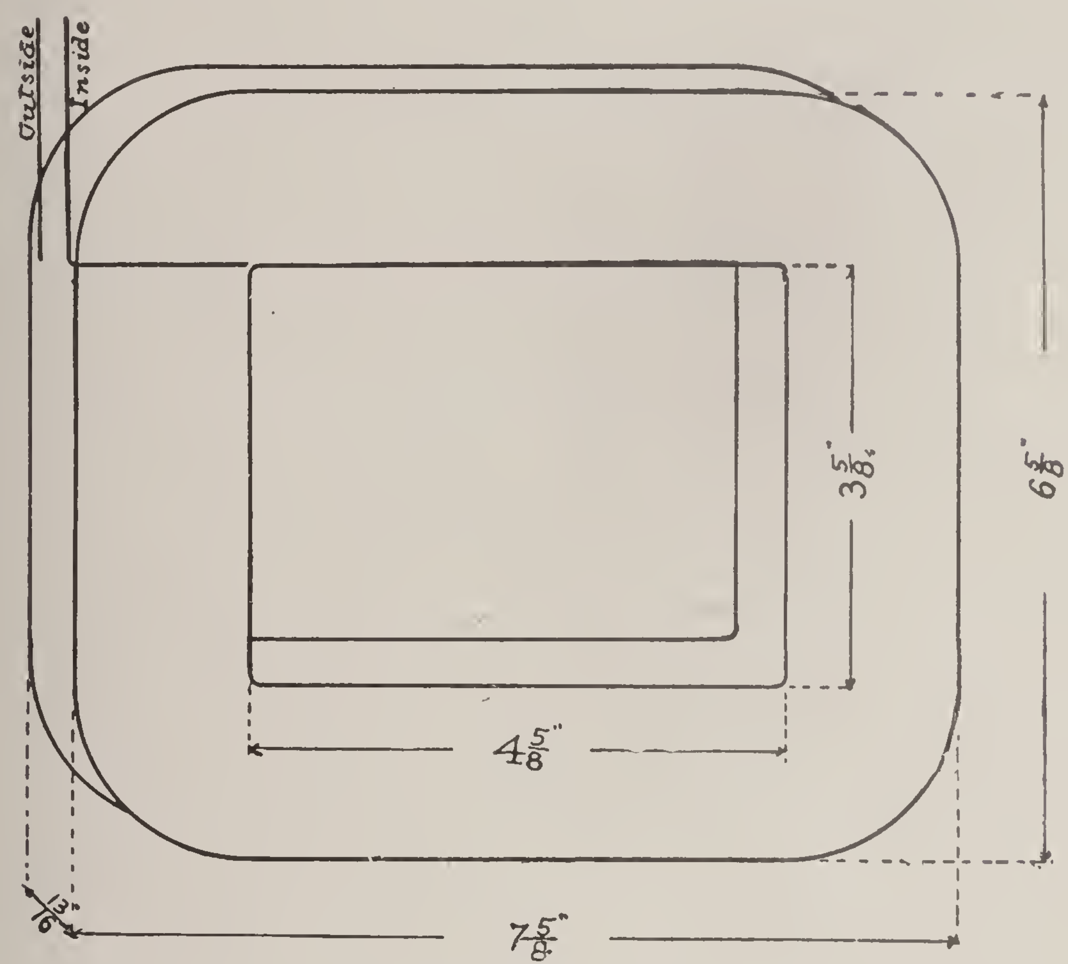


FIGURE 122.

The coils can be held in position by a few wooden blocks or wedges.

The coils can be painted with vermilion shellac and the iron with a mixture of lamp-black and ordinary varnish The brass parts may be polished. If the directions have been followed the builder will have no trouble in getting the machine to run as a motor. If he intends it as a dynamo the fields must have

some initial magnetism put into them. This can be easily done with a few cells of a battery connected to the field coils.

If the dynamo is series connected, the main binding posts, B and C, are to be short circuited by a wire. If the dynamo will not generate, after moving the brushes slowly back and forth, excite the fields with the battery, so that the poles will be reversed. The machine should then generate.

A shunt dynamo is usually sluggish in starting or "building up" as it is called. Connect the two small binding posts with a short wire, but have no connections leading from B and C. Excite the fields, and coax the machine for a few minutes, by shifting the brushes slowly. If unsuccessful, reverse the polarity and the machine should generate. Do not let the brushes spark.

It will be found that the proper speed for the machine is from 2600 to 2800 revolutions per minute, depending on the quality of iron used and the care in construction. The machine can be wound for 110 volts if desired, by using No. 20 wire on the armature four layers deep in all, and No. 22 on the fields.

If used as a motor on arc circuits, a suitable centrifugal governor must be used to keep the speed constant. The motor should be connected in circuit with double cut out switches, as shown in Figure 123. A series field may also be wound of No. 9 wire, using 6 coils as before, each having 11 layers, and seven turns per layer. These coils must be connected in series. This size of wire should be used if the motor is run on arc circuits, with the centrifugal governor arranged to cut out or in the six different coils one at a time.

As a shunt motor it should be arranged as Figure 124, with a starting rheostat in the armature circuit.

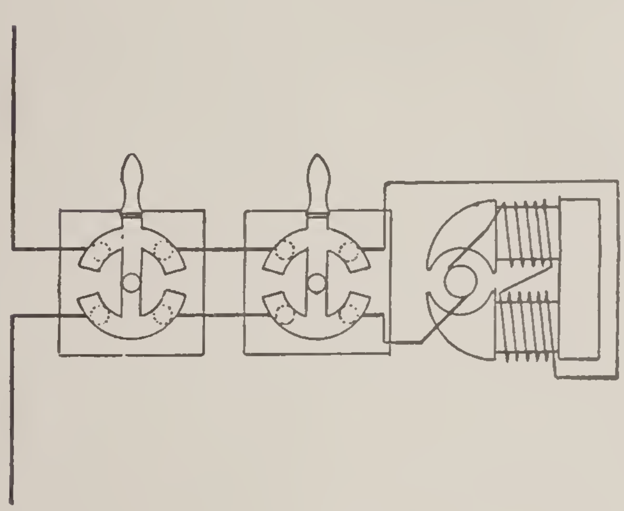


FIGURE 123.

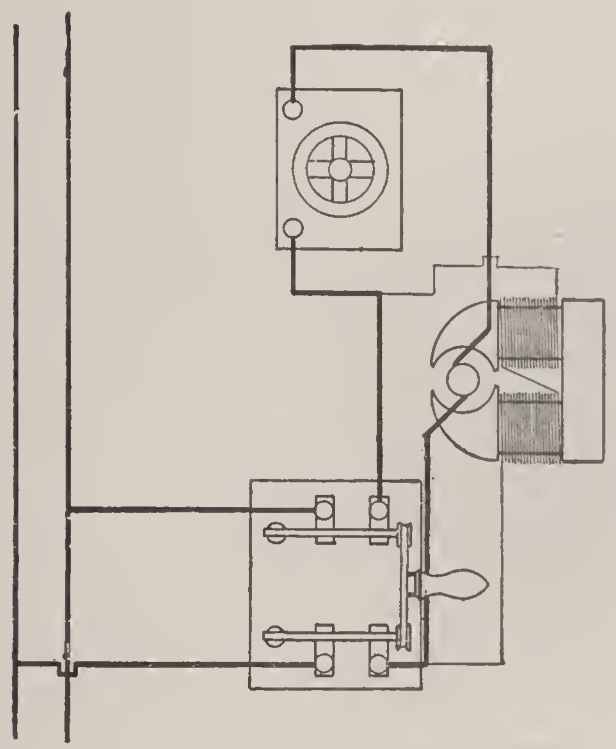


FIGURE 124.

If the builder desires to wind the machine for 220 volts the commutator should be made with 32 segments instead of 16. Extreme care should be used with the insulation for 220 volts.

An amateur is warned to desist from any attempt to make a motor for 500 volts. Aside from the difficulty of getting insulation to withstand such a pressure, the expense of the necessary fine wire is beyond the resources of beginners.

CHAPTER XII.

HOW TO BUILD A 20-LIGHT DYNAMO.

THE subject of our illustration shown in Fig. 125 represents a dynamo of familiar construction of the Edison general appearance. It is two-horse power capacity, capable of supplying twenty 16 candle power incandescent lamps, or two arc lamps of 2000 candle power each. Running as a motor it would supply about $1\frac{1}{2}$ horse power. The parts of a dynamo may be divided into three classes: — 1st, the purely stationary; 2d, the revolving; 3d, the "trimmings," which serve to connect the first and second. This chapter as has been noted will consider the first class.

To generate electricity there must be a magnetic "field of force" to act on the armature. This magnetism is made to appear in two heavy cast-iron "pole pieces" D D; they receive their magnetism from the wrought iron "cores" C C, over which the spools of wire are to be slipped. The cores are joined at their upper ends by the wrought iron block B. Unless due precaution is taken the magnetism in the pole pieces would wander through the iron base of the machine, in stead of confining its attention to the armature; a hollow casting of brass or zinc separates the pole pieces from the base. The base is of cast-iron and carries also the standards for the

shaft bearings. Two long lifting bolts A A, reach entirely through the magnets and the "grid" C, and screw into the base; unscrewing these and removing the loosened parts the armature lies open to the easiest access.

The cast-iron standards F F are, in shape, hollow circular columns mounted on rectangular pedestals; in the four corners of these are the bolts. Of the standards one is further removed from the pole pieces than the other in order to give room for the commutator; it also has a groove turned in its inner rim to hold the movable arm that carries the brushes. The standards are provided with gun metal linings for the shaft bearings. A chamber in each end catches the waste oil and holes conduct the oil to the interior of the standards where it can be drawn off.

Provided with the castings, and other material how should an amateur mechanic put the dynamo together?

Plane the bottom of the base where it is to touch the floor and drill the holes in the four projections; then plane the upper surface in the three places where parts are mounted. Screw the standards in position, as nearly as can be estimated. Now true out the holes in their upper ends, between lathe centers, unless a boring hole is convenient. Plane the grid, top and bottom, and secure it in position with two dowel pins, and a few temporary bolts. Plane the pole pieces, top and bottom, and bore the bolt holes through. Adjust them in position on the grid so that their center will correspond with the centre line of the standards; mark the position for the bolt holes in the grid. Now drill through the latter, and tap out the holes in the base; put two dowel pins between each pole piece and the grid, so that there may be no skewing.

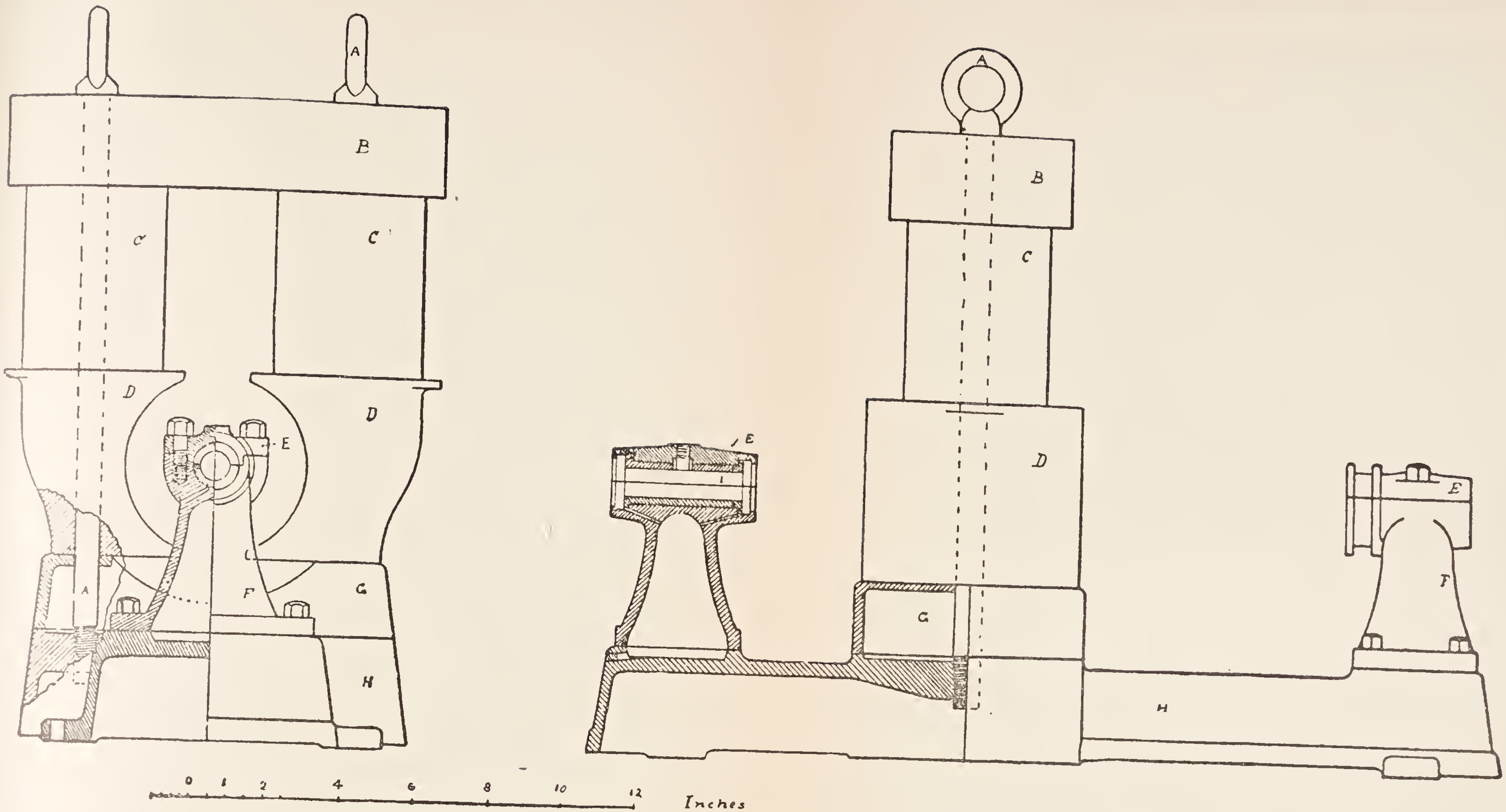


FIGURE 125.

The cores should be fairly smooth and have the ends square; for this purpose the bolt holes had better be drilled first and the cores turned on the arbor. The magnetic yoke B need be planed on its lower surface only. Drill the holes through this and the parts are ready to be bolted together. Get a boring bar that fits in the holes in the standards and bore out the pole pieces to the right diameter 5°. The boring need not be very smooth, only the armature as it revolves should have equal clearance everywhere.

The linings or bearings should be made in halves so as to take up the wear, and allow easy scraping and cleaning. Nipples in the upper halves enter the oil cup holes in the caps to prevent the lining from turning: shoulders at the ends prevent longitudinal motion.

When all this has been done the builder is ready, if his courage is good, to undertake the armature and commutator.

Rotating Parts.—In the armature and commutator the builder will find good tests of his mechanical skill.

The revolving parts of a dynamo consist of shaft, armature, commutator and pulley, which are shown in figure 126.

Good machine steel should be used for the shaft A, and it must be smooth and straight. To prevent springing, and afford ease in putting the armature together, the diameter in the center is $1\frac{1}{16}$ inches. This portion is 6 inches long and has threads, 16 to the inch, cut half an inch up at each end. Extending from the threaded portion to the bearing size, the shaft is $\frac{15}{16}$ inch, at the bearings $\frac{3}{4}$ inch, and for the pulley $\frac{11}{16}$ inch. The shoulders at the beginning of the bearings serve to keep the armature between the pole pieces; about $\frac{1}{8}$ inch end-play will be useful to give the armature a little liberty, and allow the commutator to wear smoothly.

Wrought iron boiler plate $\frac{1}{2}$ inch in thickness, will do for the armature heads "B B." They should be chucked in a lathe and turned on one face, the hole drilled and threaded to fit the shaft. For turning the other side and getting to right diameter, it will be best to screw them on a short stiff arbor. This arbor will be necessary for the next operation; 32 slots $\frac{1}{16}$ inch wide and $\frac{1}{2}$ inch deep are to be cut in the rim of the heads. This should be done in a milling machine. These slots are to receive pegs that keep in position the copper wire with which the armature is wound.

The center "C' of an armature called the core is not of solid iron, as the rapid magnetization and demagnetization would heat a solid mass sufficient to burn the insulation of the wire. Sheets of the softest iron, about $\frac{1}{100}$ inch thick, separated by tissue paper, are used. For this machine the sheets should be about $4\frac{1}{2}$ inches in diameter with a $1\frac{1}{16}$ inch hole in center.

Screw one of the heads very tightly on the shaft and lay on a sheet of paper, then a sheet of iron, another of paper, and so on until the right amount is built up. It will require a few trials to determine just the number of sheets necessary.

Screw on the other head as tightly as possible and see that the whole length is just right—6 inches—the same as the width of the pole pieces. Holes may be drilled in the heads to admit the use of spanner wrenches for tightening. A $\frac{3}{8}$ inch bolt covered with paper, except at the threaded portion, inserted through a $\frac{7}{16}$ inch drilled hole, must be put in the core, as shown, to bind the whole together. With this precaution the sheets cannot slip nor the heads unscrew. The armature is now to be put in a lathe, and with suitable steady rests to prevent springing the shaft, turned smoothly to its correct diameter, $4\frac{3}{8}$ inches, the heads beveled and corners rounded.

There are several ways to make a good commutator, but any one of them requires time and care. It is the only part of a dynamo that receives serious wear; besides a poorly made

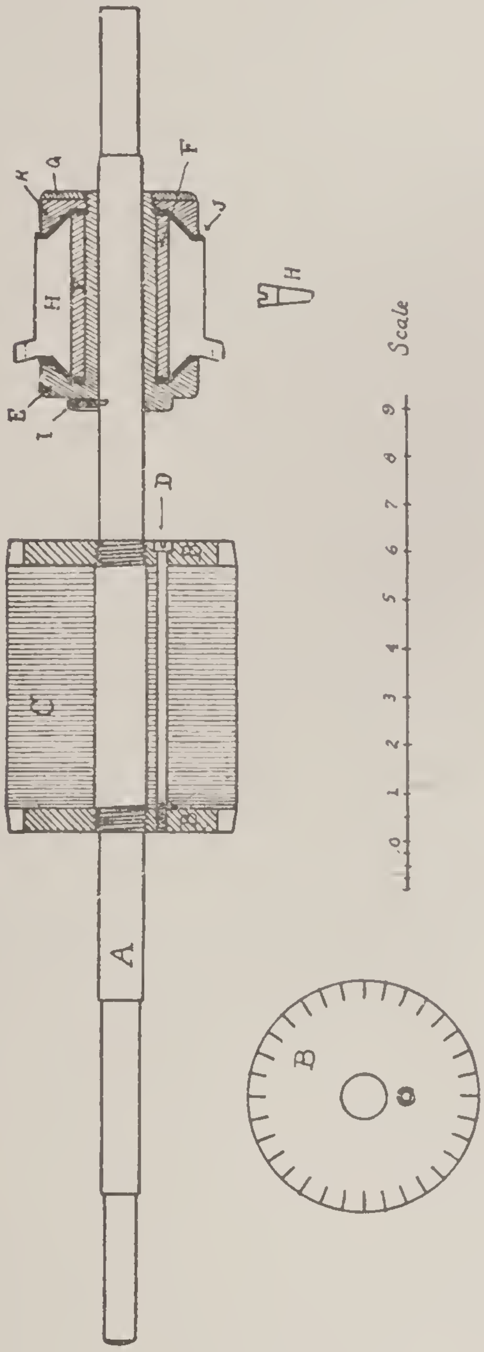


FIGURE 126.

commutator will spark so as to work its own destruction.

Get a casting of as nearly pure copper as possible and turn it to the shape shown in section at H. Mount it on an arbor in a milling machine, and saw it with a cutter $\frac{1}{16}$ inch

thick, almost through, into 32 sections. Intermediate slots $\frac{3}{16}$ inch deep, $\frac{1}{16}$ inch wide, in the flange portion, will make allowance for connecting the wires with which the armature is to be wound. Fit mica to each of the dividing cuts and make the pieces of the same shape as the commutator segment. Washers "J J" of vulcanized fiber are turned to conform to the shape of the brass shell E and copper segments H. The ring K is of the same shape as the head of the shell E, and is to be forced up by the nut G. With a hack saw separate the segments H entirely, and file off the burr from each. These with the mica between can be set up to form a cylinder around the fiber bushing F. It will be well to make the outside diameter of this bushing about $\frac{1}{32}$ inch less than the hole in the copper body of the commutator so that when the shell and ring are put in place and the nut screwed up, the mica may be tightly pressed between the segments. After the outside has been turned and smoothed with fine sandpaper the commutator will be ready to put on the shaft. For securing it in position a set screw may be used, the blank end of which enters the shaft $\frac{1}{8}$ of an inch.

The pulley is of no special construction. An ordinary iron one will do, but a paper or wooden face will have its advantages; 4 inches in diameter and 3 inches face will be sufficient. Set screws butting on the shaft are permissible in a small machine like this, but it will be better if they rest upon a key.

Last of all for this stage of the work, the armature should be set upon horizontal ways and balanced. This can easily be accomplished by drilling $\frac{1}{4}$ inch holes through the heads on the heavy side.

Trimmings.—By the trimmings of a dynamo the reader is not to understand that these parts are for ornament only. In fact they are essential, as they serve to connect the revolving with the stationary parts, to connect the dynamo with the circuit it is intended to operate, and to provide means for regulating the action of the machine.

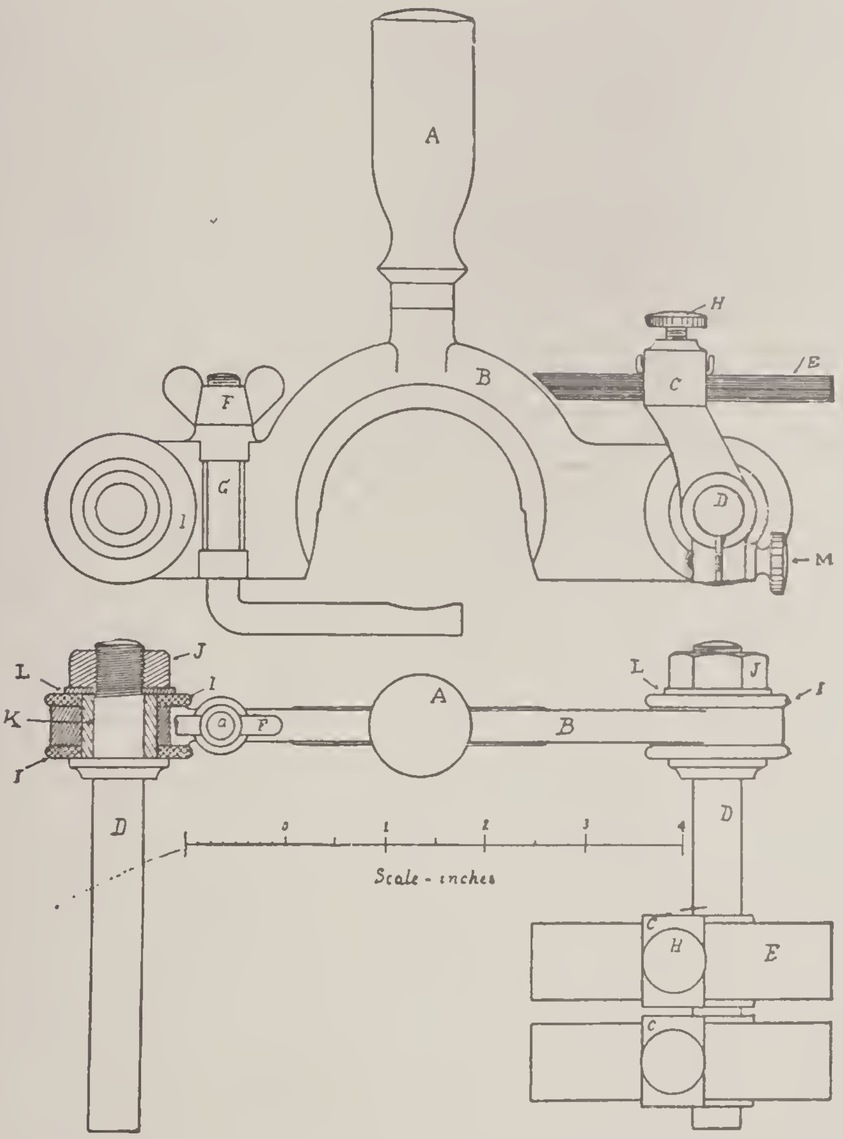


FIGURE 127.

Like the main part of the dynamo these accessory parts may be any one of a variety of forms. These are shown in figures 127 and 128.

The "brushes" are a very important part of a dynamo;

they should be very springy, yet bear firmly on the commutator. Those shown here at E E, are two of the set of four to be used. They consist of a large number of leaf copper ribbons laid one on another and soldered at one end. The other end is beveled to fit the commutator. Two independent brushes are used on each side so that one may be removed and repaired or adjusted without stopping the dynamo.

The brush holders C C are of brass castings. Through one end of each a slot $\frac{3}{16} \times \frac{3}{8}$ inch admits the $\frac{3}{4} \times \frac{1}{4}$ inch brush; a suitable thumb screw and jam plate holds the brush securely in position. The opposite end of the holder is sawed through to a half inch hole and pinched by a thumb screw M against the brass spindle D. Hard rubber washers and bushings clearly shown in the figure insulate the spindles from their holder B, called the yoke.

The position of the brushes on the commutator must be adjustable; for this purpose the yoke has its center bored out to fit the groove turned on the inner rim of one of the bearings d escribed in the first article. To prevent undue movig a clamp consisting of a bent rod G tightened by the thumb nut F binds against the lower part of the groove. There will be sufficient elasticity in the rod to allow the rod to be moved when desired without loosening the nut, yet the vibration or jarring of the machine will be insufficient to alter the position after once being set.

At L washers are shown to receive the direct action of the nuts, but they also serve to attach the flexible cables that conduct the current. One side, not shown, should be extended into a tang about half an inch wide; this can be curled so as to allow the cables to enter and be soldered in.

The cables lead to the connection board. This switch or connection board will vary according to the purpose for which the machine is built. Shunt, series or compound winding of the wires of the dynamo or motor will alter the connections. The one shown is for a shunt dynamo, and is of such construction as to be readily adapted to other conditions. A maple

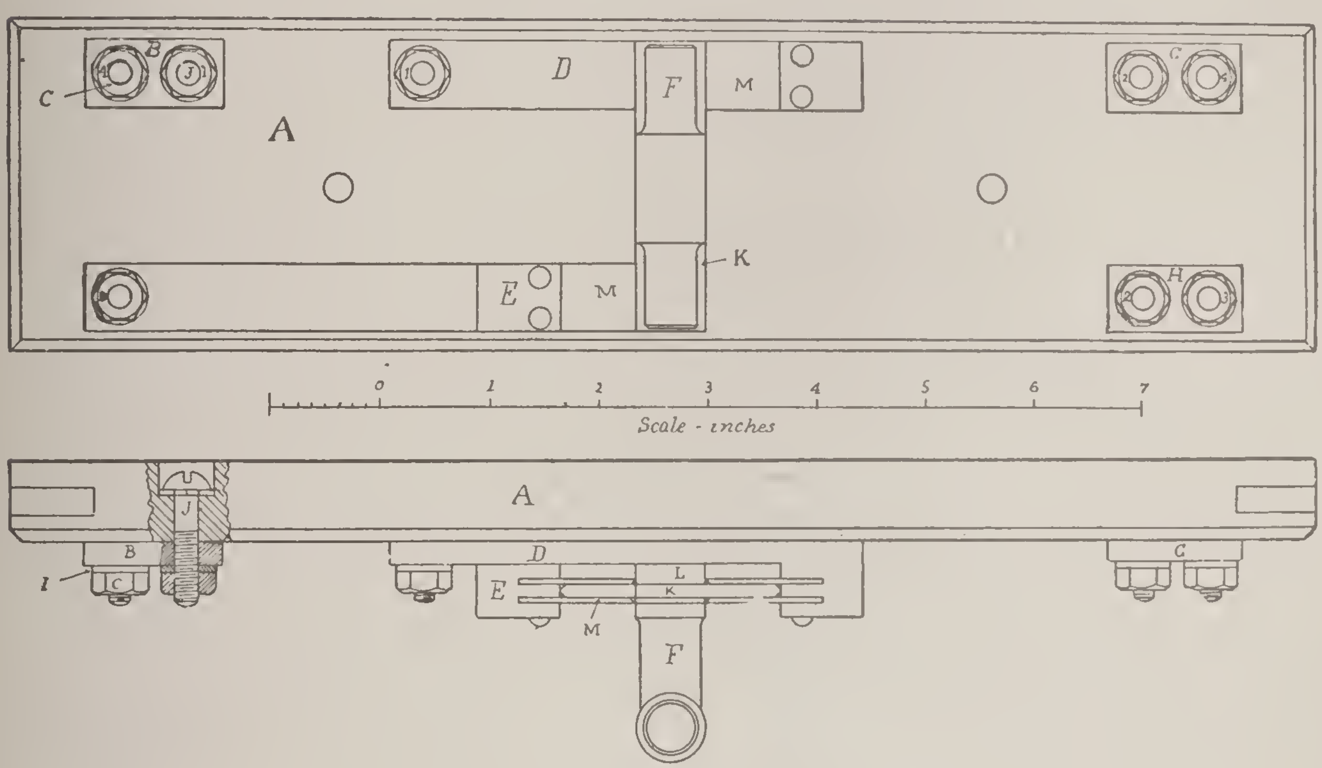


FIGURE 128.

board forms the base. As it fits on the commutator side of the magnetic yoke of the dynamo, it must be of the same size—3 x 12 inches. The switch in the center consists of a sheet brass blade K, $\frac{1}{8}$ inch thick; at each end is a right angled projection that enters between the brass contacts M, held in brass blocks E and D. The surfaces of each must be scraped or filed to make uniform contact. The builder may use his own ingenuity in getting the switch blade pivoted. One way is suggested. A stud I is held rigidly in the board by a countersunk nut, the blade K attached to the hard rubber handle F, on this.

A pin through F, and through an elongated hole in the stud will limit the amount to which the switch may be opened, yet keep the blade in the right position to enter the contacts M.

Contact blocks B, and H are also of brass held on the board by screws J as shown. The holes in the back of the board should be filled with resin or shellac. Wires for connections are to be held under the washers and nuts.

The conventional form of binding posts seen on bells and telegraph instruments are not suitable for a dynamo. Besides offering insufficient surface, thumb screws easily rattle loose. Safety fuses are desirable in this machine, and places are provided for two, one on each side of the circuit. The current should pass from one set of brush holders by a flexible cable to the clamp 3 on E; through the switch blade to 1 on D, through a fuse to 1 on B; thence from 4 to the lamps, or whatever the dynamo supplies; back to 4 on C, to 2, through a fuse to 2 on H, and by a flexible cable from 3 on H, to the brush holders on the opposite side of the commutator.

No description has yet been given for the field spools. These are very simple, consisting of $\frac{1}{8}$ inch brass flanges or rings united by tin cylinders. Allowance should be made for winding wire 1 inch deep radially. The spools should slip easily over the cores and be short enough to allow the magnetic yoke to rest evenly on the cores.

Thus far the builder has done a large amount of work, but the whereabouts of the electricity, for which the dynamo is intended, remains unseen.

Let us suppose that the builder wishes to supply 20 incandescent lamps. These may be conveniently 75-volt lamps. The armature should then be "wound" with No 15 (B. & S.

gauge) double cotton-covered copper wire; 8 pounds will be sufficient. Insulate the core thoroughly with paper and shellac, $\frac{1}{16}$ inch thick in all. Cut through into the slots in the heads and drive in the 32 leatheroid pegs in each. To show these on a larger scale the armature is represented as having only 8 pegs. (See Figure 129).

The winding can be conveniently done in a lathe. Leave an end of 6 or 8 inches at the commutator side and pass the wire between any two pegs, then parallel with the shaft, be-

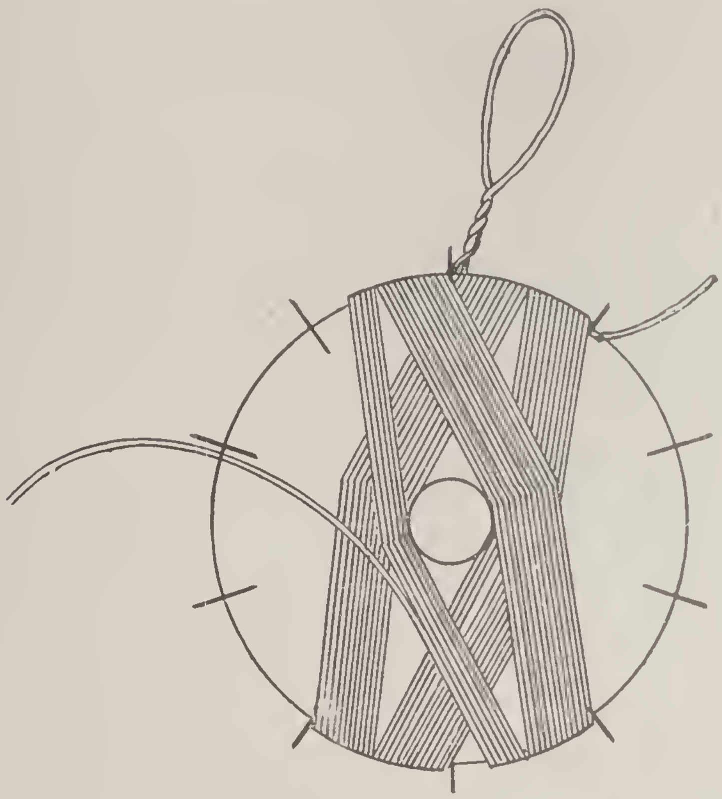


FIGURE 129.

tween corresponding pegs in the other head, across the end, back between pegs diametrically opposite to the starting point. Continue the wire alongside the first turn until the whole space is filled. Six turns will do this. Do not cut the wire, but make a loop of 4 or 6 inches and wind the space between the next pegs likewise, make a second loop and wind the third space and so on until the whole surface of the core is covered with

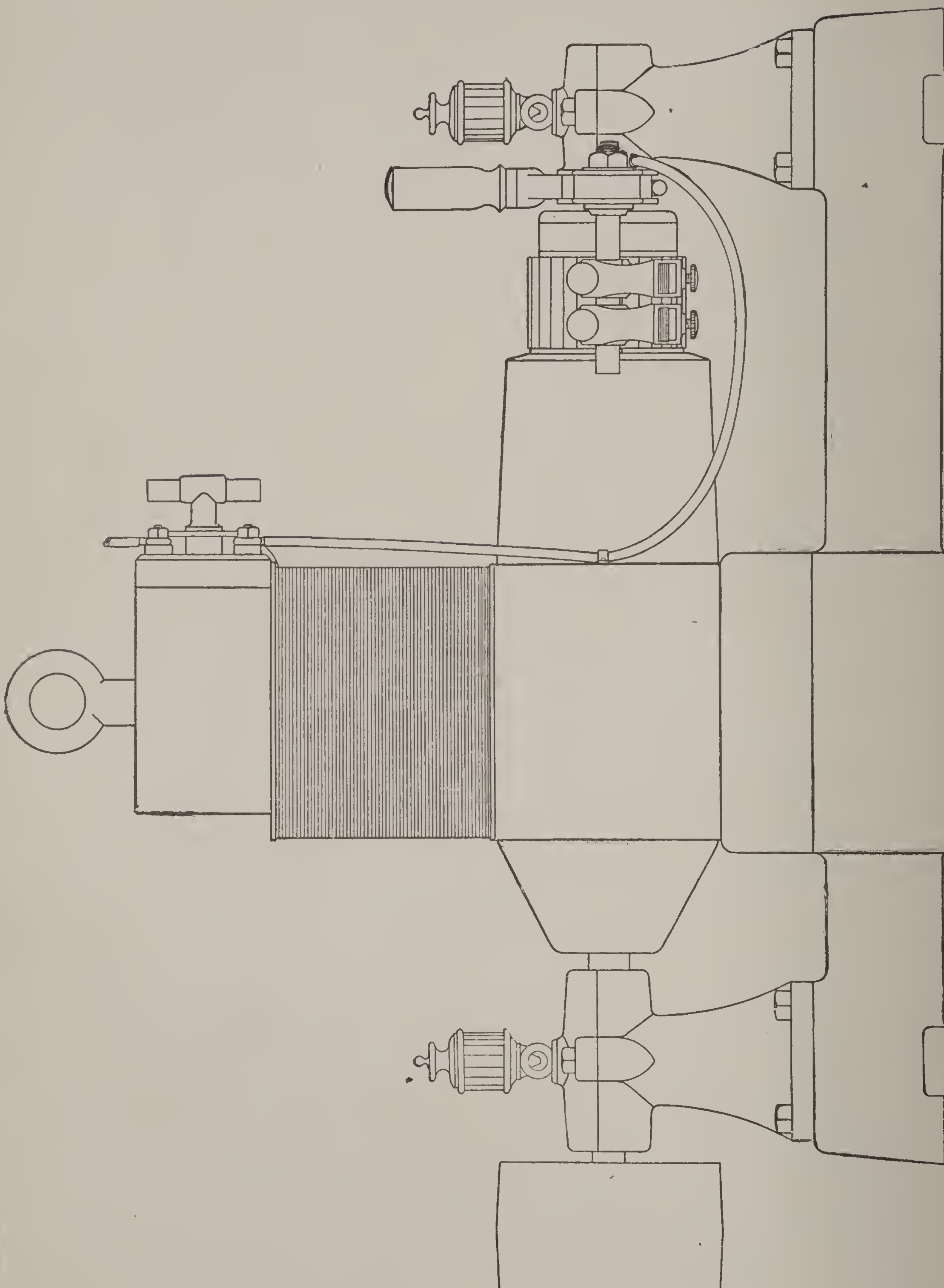


FIGURE 130.

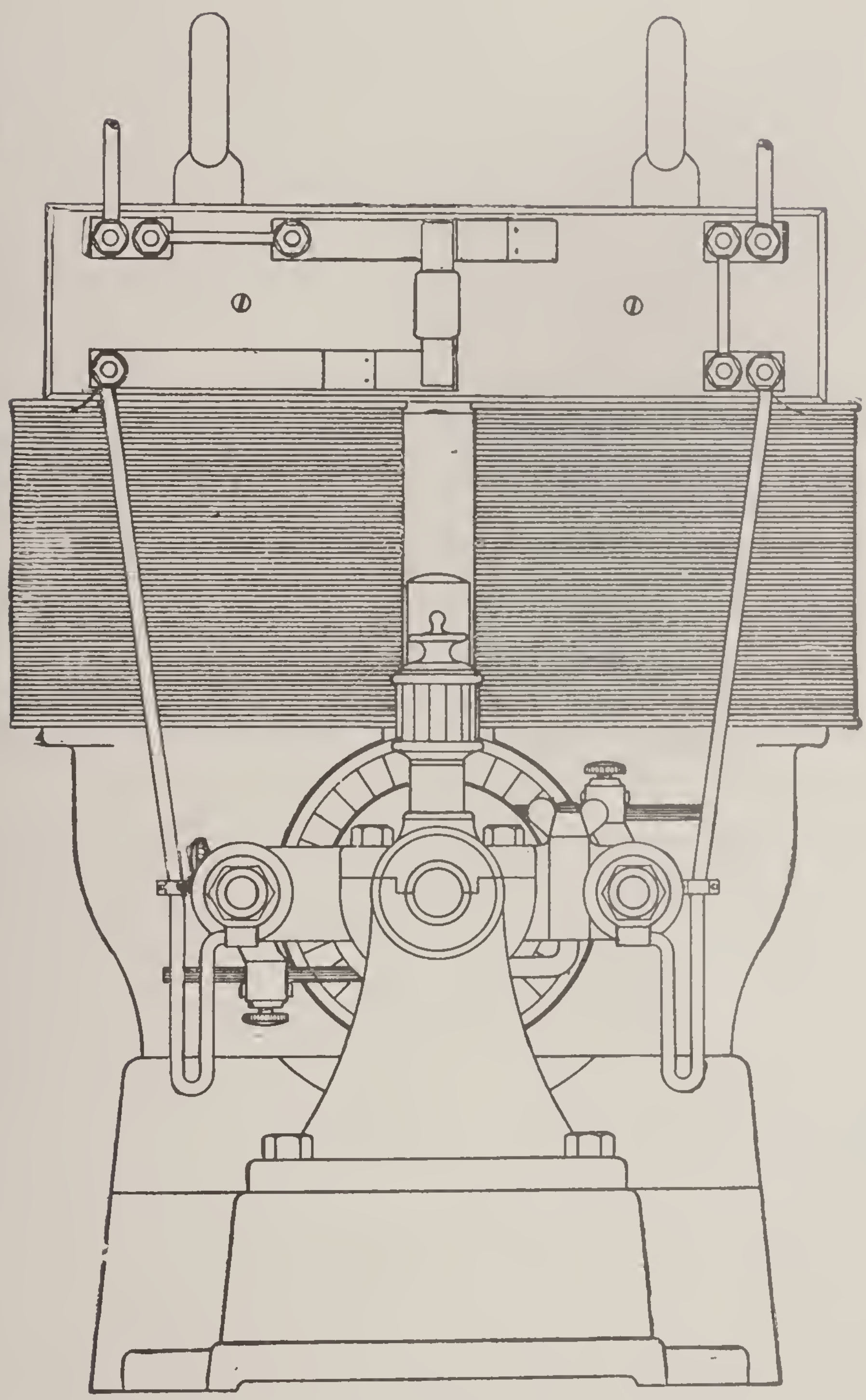


FIGURE 131.

one layer of wire. This will give 16 loops for connecting with the commutator. Thirty-two loops, however, are needed. Continue a second layer on top of the first between the same pegs. When this is done join the ends with the beginning and the 2 loops are ready to be soldered into the slots in the commutator ears. Do not connect these straight, but give them a "lead," so that when running, the brushes may be in a convenient horizontal position. Connect a loop with the fourth segment away from the nearest one and let the other loops follow in the same order.

Upon paper strips in four equally distant places wind tightly wrapping wires of fine brass. This will keep the copper wire in place.

Usually a hood of canvas is put over the ends of the armature to give a neat appearance.

Insulate the spools like the armature and wind 10 pounds of No. 23 wire on each and connect the two spools in series.

At 2,200 revolutions per minute this machine should give a current of 80 volts and has a capacity of 15 amperes.

The exact winding of a dynamo depends on such a variety of considerations that for a particular case the builder is advised to consult an electrician, but the winding here indicated will be easy, and the machine will supply a current of convenient strength for a large variety of experiments.

CHAPTER XIII.

HOW TO BUILD A 1000 WATT ALTERNATING CURRENT DYNAMO OR MOTOR.

IN their natural state dynamic currents of electricity are alternating in direction. Continuous currents are procurable from dynamos by the use of "commutators," which "rectify" the successive alternations—send them through the exterior circuit in one direction. In "alternators" the current is supplied to the circuit in the same form as it is generated in the revolving armature.

Alternating current dynamos have the advantage that with the same weight of materials about twice the output can be secured which is possible with direct current apparatus. Added the simplicity and durability of the collector rings, in place of the troublesome commutator, and the ability to transform its potential to any desired value, and the alternator offers substantial economic features. Its disadvantages consist in its inability to excite its own field magnets, and to run ordinary arc lamps and motors.

This chapter describes a "single phase" dynamo, weighing about 150 pounds, having an easy output of 1000 watts, but can furnish 1500 watts without danger. That is, wound for 50 volts, it will furnish 20 to 30 amperes, or light 16 to 24 ordinary

16 c. p. incandescent lamps. It is possible, also, to use the machine as a synchronous motor of about 1 horse power capacity, but some exterior devices must be employed to revolve the armature at full speed before it can assume its load. In either case field excitation is to be supplied from a separate continuous current dynamo.

Assembled views of the machine are given in Figures 133 and 134. In general the mechanical construction consists of a base supporting two pedestals for self-oiling bearings, and, between them, the field magnets. Besides the main driving pulley the shaft is extended at the collector end for carrying a smaller pulley to drive an "exciter" for the field magnets. Electrically the armature is "toothed," with the coils wound around the projections; the field is laminated with inwardly projecting salient poles.

The detailed construction may be divided as follows:—

. Base and bearings.
2. Field magnets.
3. Armature, shaft and pulleys.
4. Collector rings.
5. Brushes, holders and studs.
6. Winding.
7. Connections.
8. Assembling and using.

Base and Bearings.—Ordinary cast-iron is suitable for these parts, as they form no part of the magnetic circuit. Figure 132 shows the base in detail. It is box-like, with an opening in the center to admit the field, and has various raised surfaces, or "bosses," on which the upper structures rest. The machine work will consist in planing first the four bottom corners, then

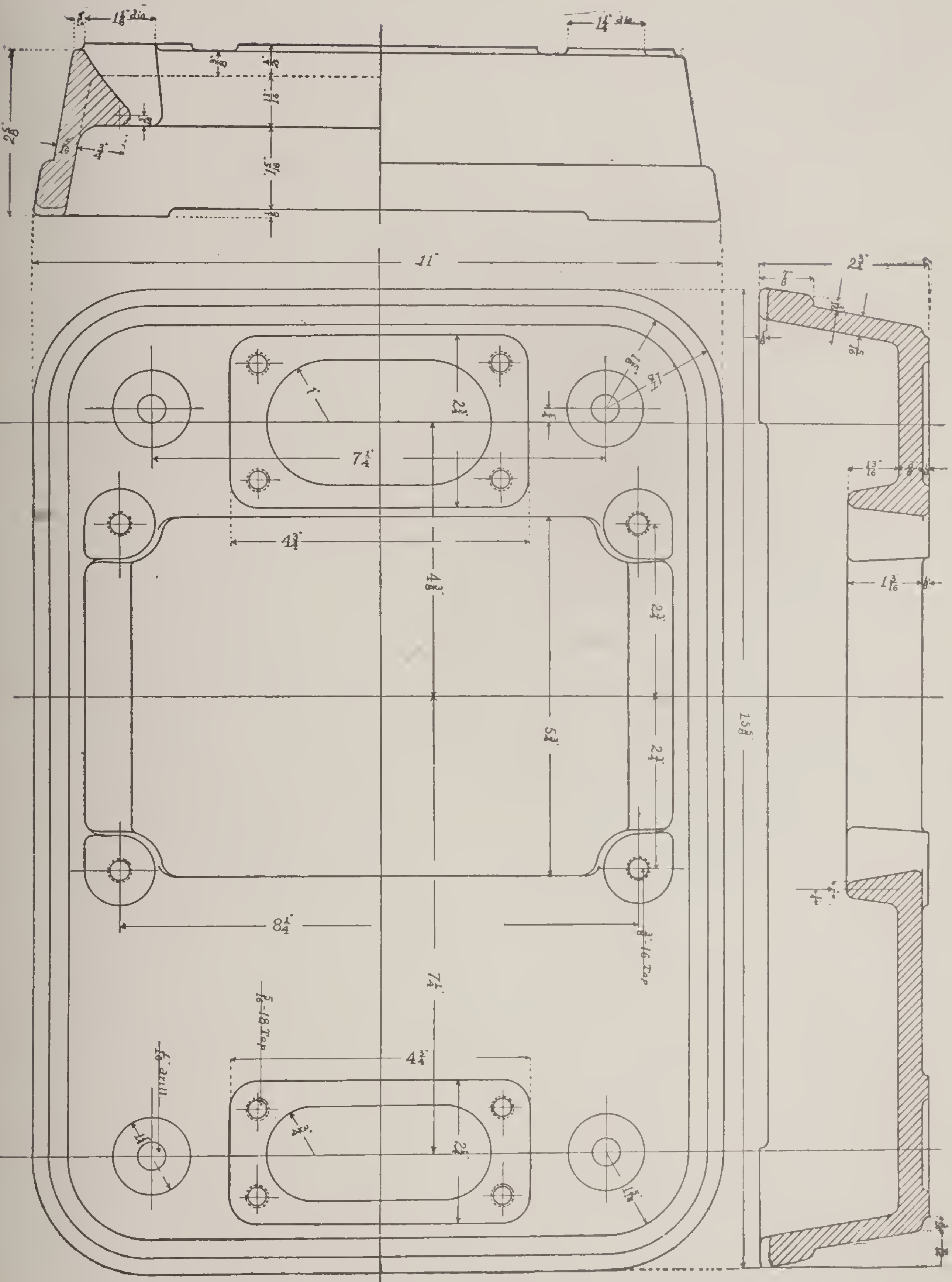


FIGURE 13.

the necessary spots on the upper surface. Drill the $\frac{7}{16}$ inch holes in the corners, which are to admit holding-down bolts.

The pedestals (Figure 135) may next be machined. Plane the bottoms first, then the upper surfaces; plane also the caps,

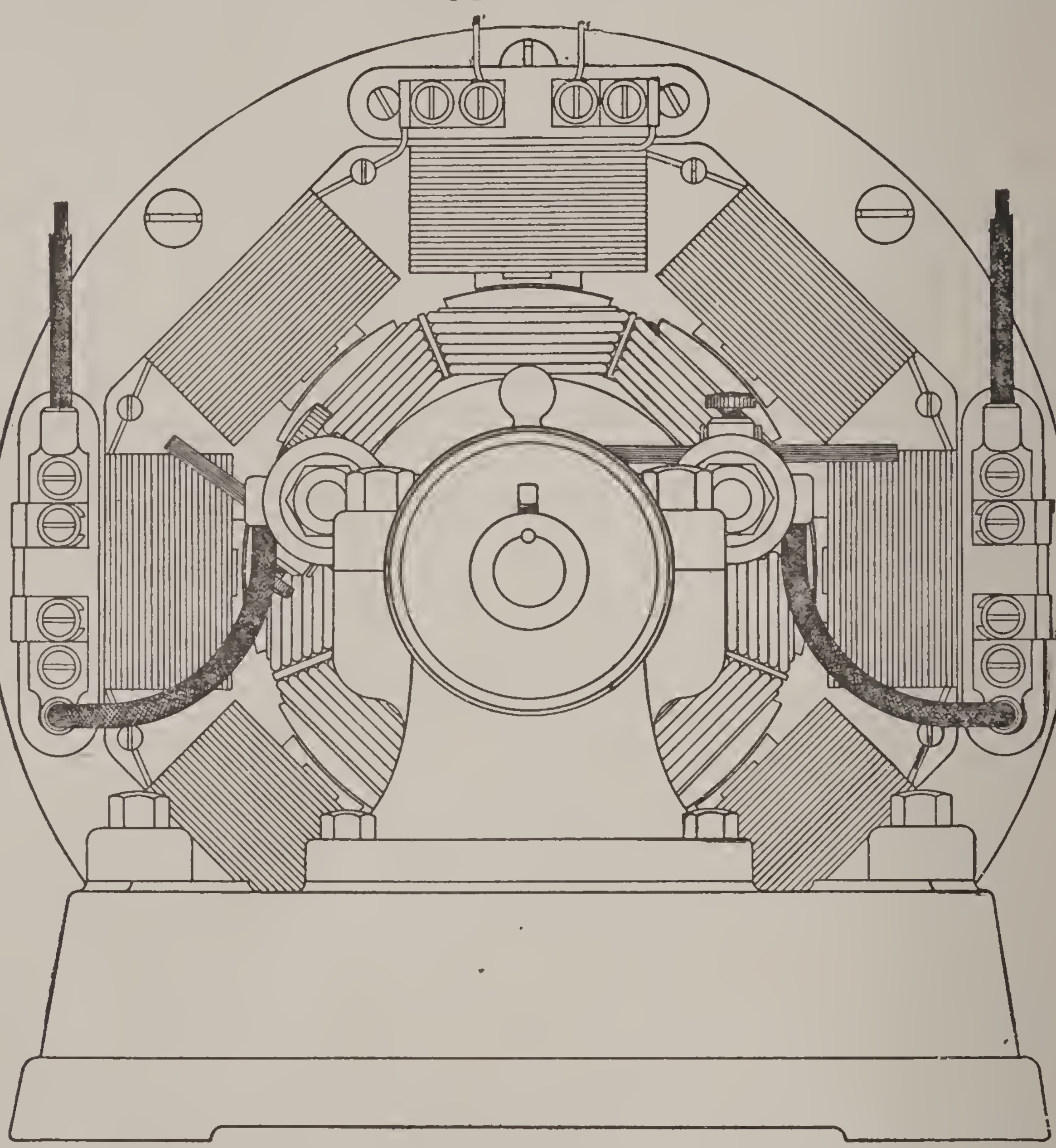


FIGURE 133.

and screw them to the pedestals by means of the $1\frac{1}{2}$-$\frac{3}{8}$-16 hexagon cap screws. In the lower ledges drill the $\frac{11}{32}$-inch holes, and clamp the pedestals in their proper places on the base. Set the $\frac{11}{32}$-inch drill through the holes just drilled, and cut into the base about $\frac{1}{8}$ inch. Mark the parts, so that they may be

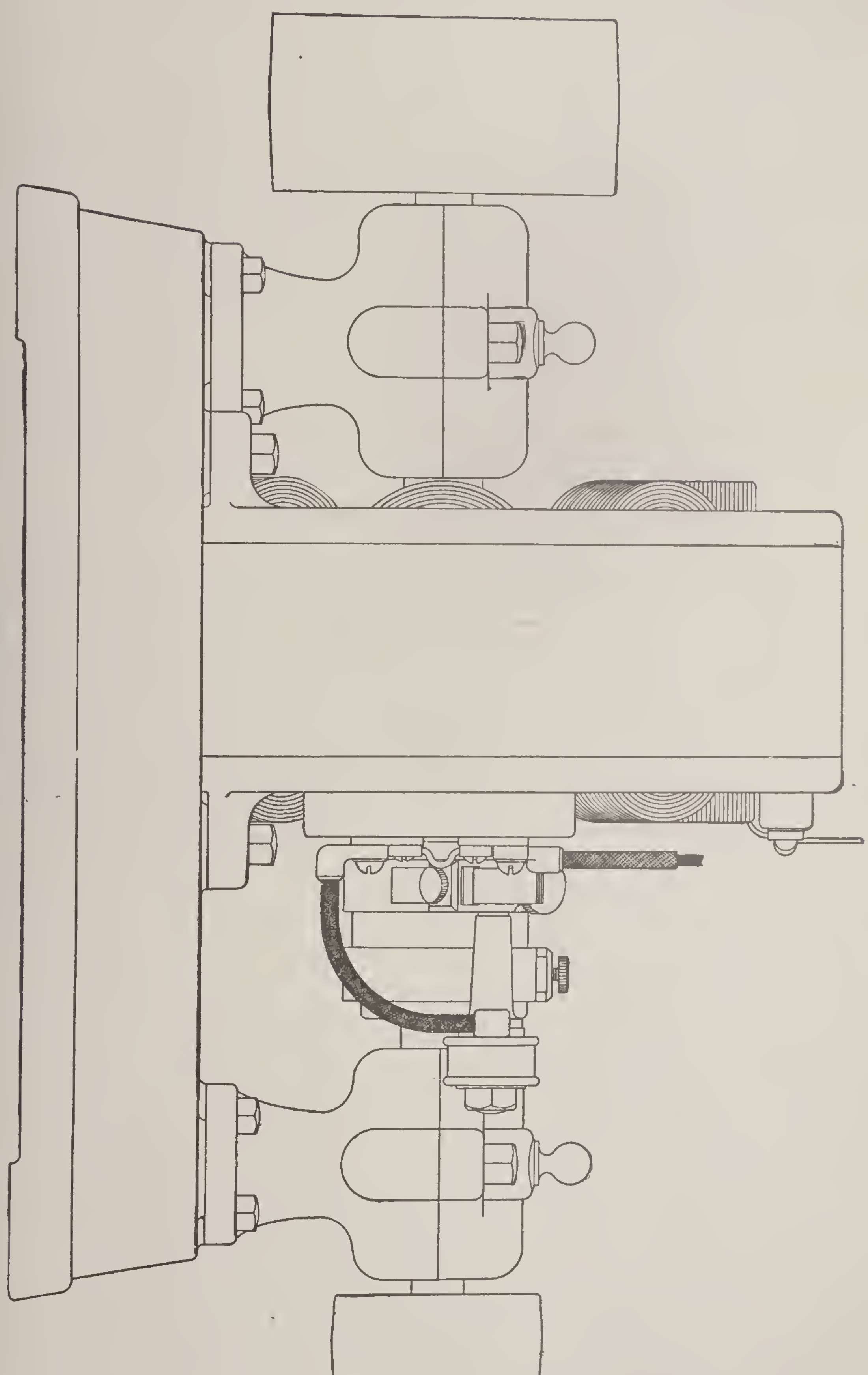


FIGURE 134.

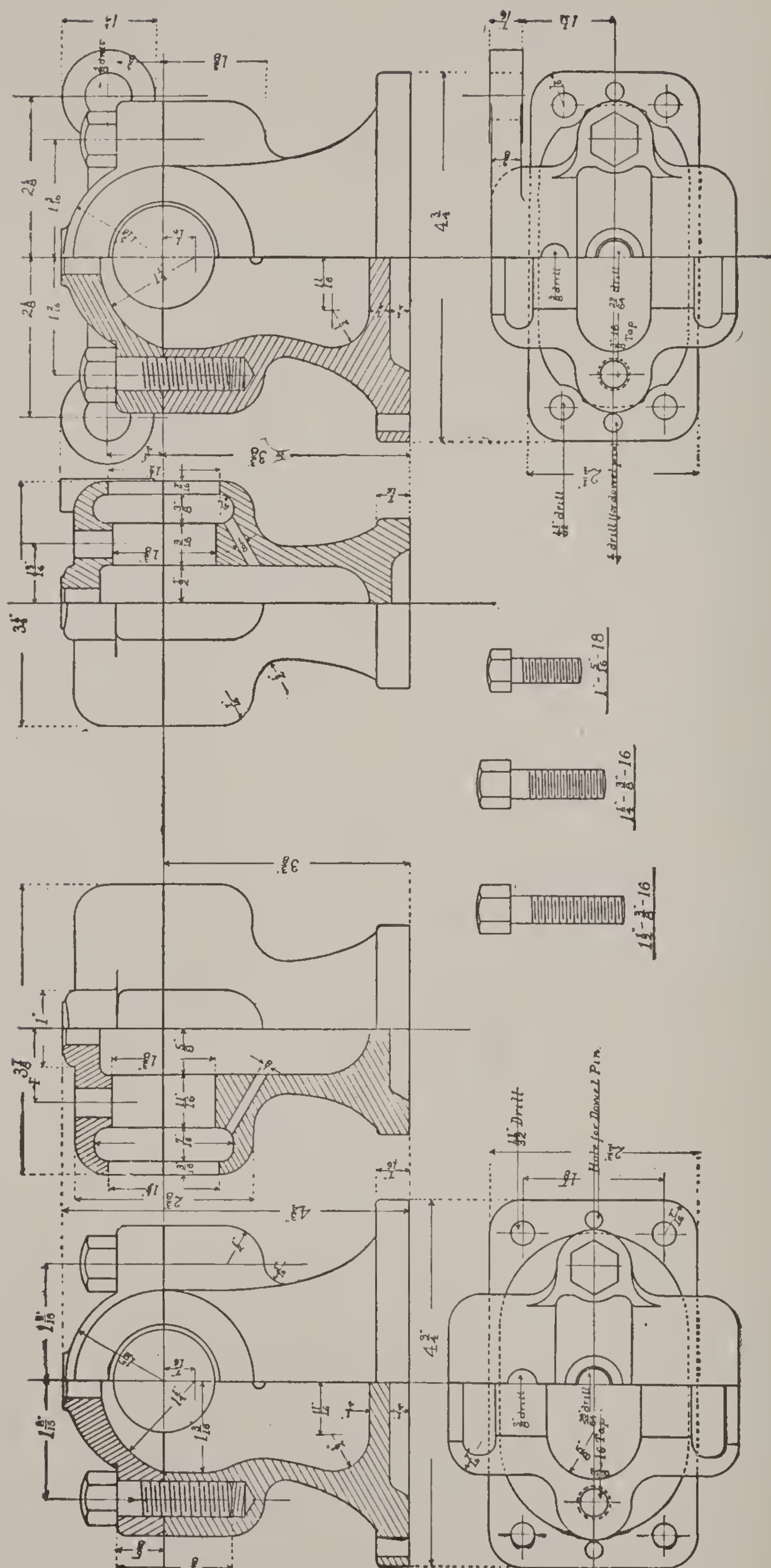


FIGURE 135.

returned to the proper locations; remove the pedestals, and run a $\frac{1}{4}$-inch drill through the depressions, and tap the holes $\frac{5}{16}$-inch-18. Replace the pedestals, and bolt them in place with the 1-$\frac{5}{16}$-inch-18 hexagon cap screws. Drill $\frac{1}{4}$-inch holes on opposite sides as shown, and extending into the base about $\frac{1}{4}$ inch. Drive in steel pins that may enter the base $\frac{3}{16}$ inch and be filed off on the upper end, even with the ledge on the pedestal. These are to act as dowels for preserving the alignment of the bearings.

Bolt the structure, as it now stands, to the travelling-carriage of a lathe, and bore out the holes in the pedestals to $1\frac{3}{8}$-inch diameter. The castings should be so made as to require cutting in two narrow belts only. Drill the $\frac{29}{64}$-inch and the $\frac{3}{8}$-inch holes in the caps for the bearings, and the $\frac{1}{8}$-inch slanting holes that lead from the grooves to the oil-well. Holes may also be drilled and tapped for inserting small pet-cocks for drawing off the oil when necessary. The oil-wells must be thoroughly cleaned from scale and sand that would otherwise cut the bearings. After scraping as thoroughly as possible, it would be well to let the cavities remain filled with water for a week or two, that the rust may remove the remaining grit.

Linings, or bushings (Figure 136) for the bearings may be either of babbitt or gun metal. Drill out the center holes and ream them to $\frac{7}{8}$ inch diameter. Turn the outsides to $1\frac{3}{8}$ inch on an eccentric arbor, gash out the central slots for the oil-rings; round out the internal corners and cut the grooves. Oiling-rings may be made of castings or cut from a suitable size of brass tubes. Bevel the edges as shown. Plugs for filling the holes in the caps may be made from brass rod.

Field Magnets. For holding the laminations (Figure 137) of the field together cast iron rings or flanges are to be used.

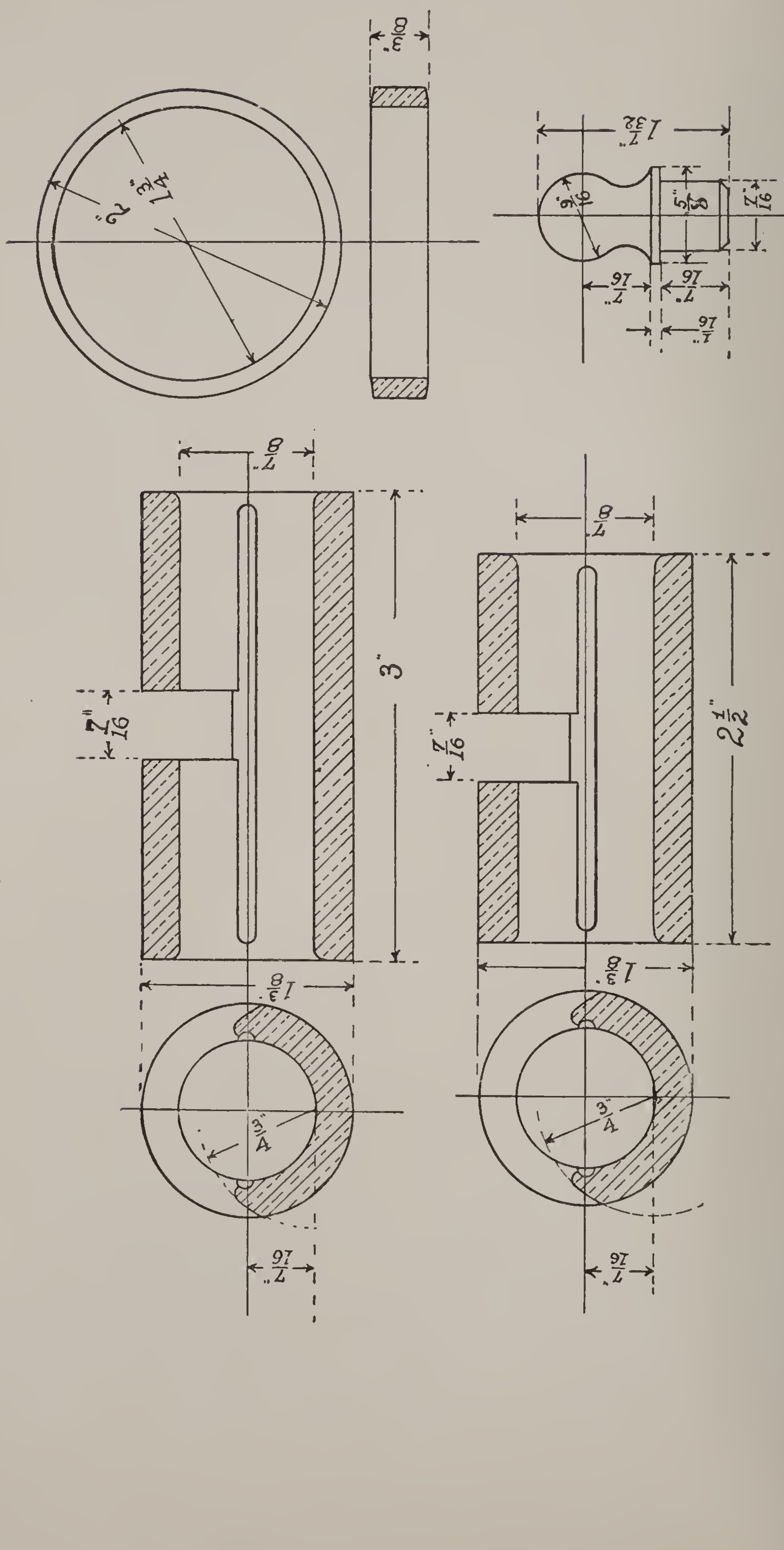


FIGURE 136.

See Figure 138. If cast flat, the surfaces which press against the sheets will not require planing. In one flange, drill and countersink $\frac{1}{32}$-inch holes as shown, also drill and tap the six holes for the connection boards; the other flange requires nothing at this stage. If punchings of sheet iron cannot be obtained, as

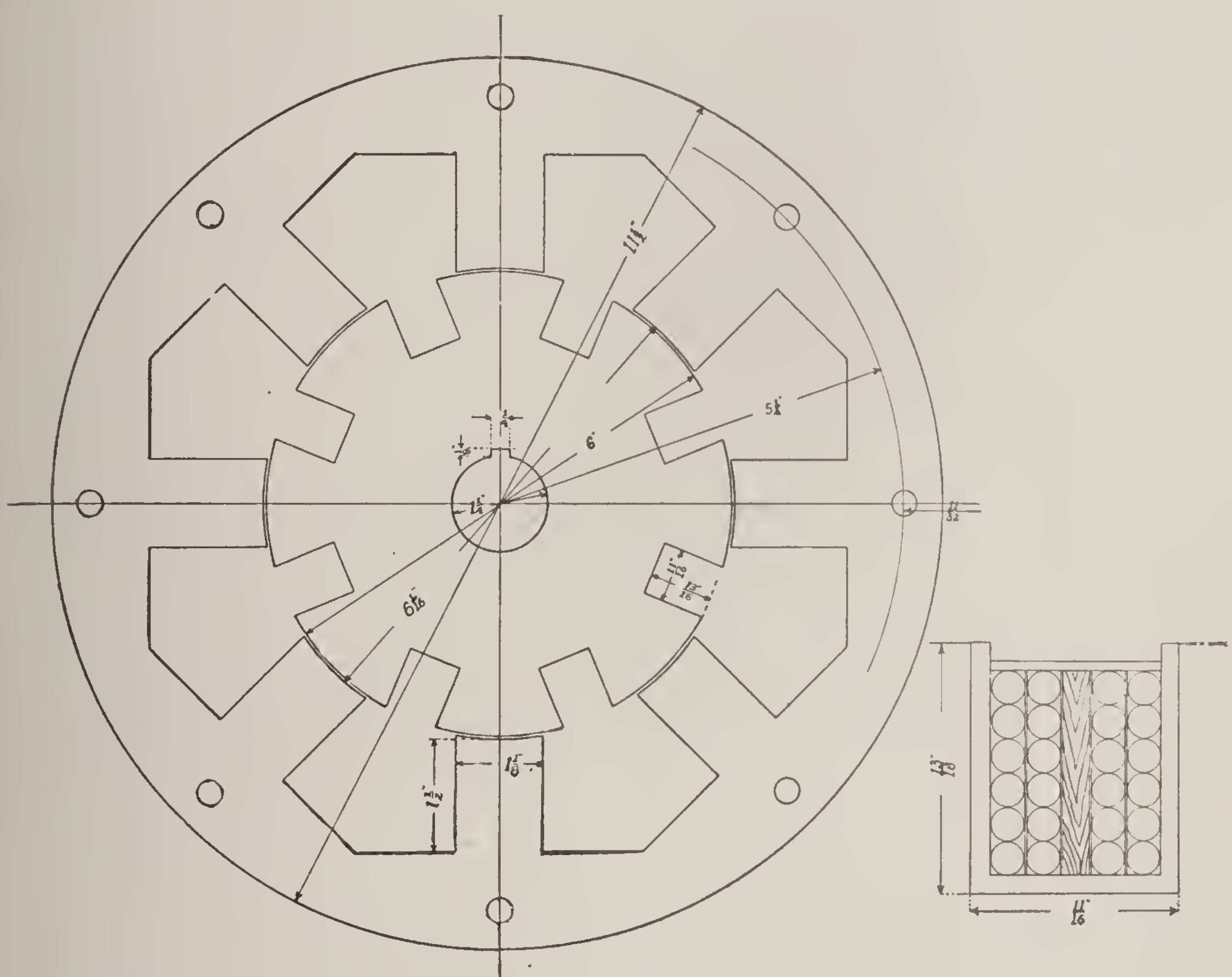


FIGURE 137.

shown in Figure 137, sheets $11\frac{1}{2}$ inches outside diameter, with 6 inch holes may be procured, and clamped between the two flanges. Use a sufficient number of sheets to make a compact laminated mass three inches thick. Continue the $\frac{1}{32}$-inch drill in two of the holes in the flange, through the sheets; as soon as the other flange is reached, finish with $\frac{1}{4}$-inch drill and tap

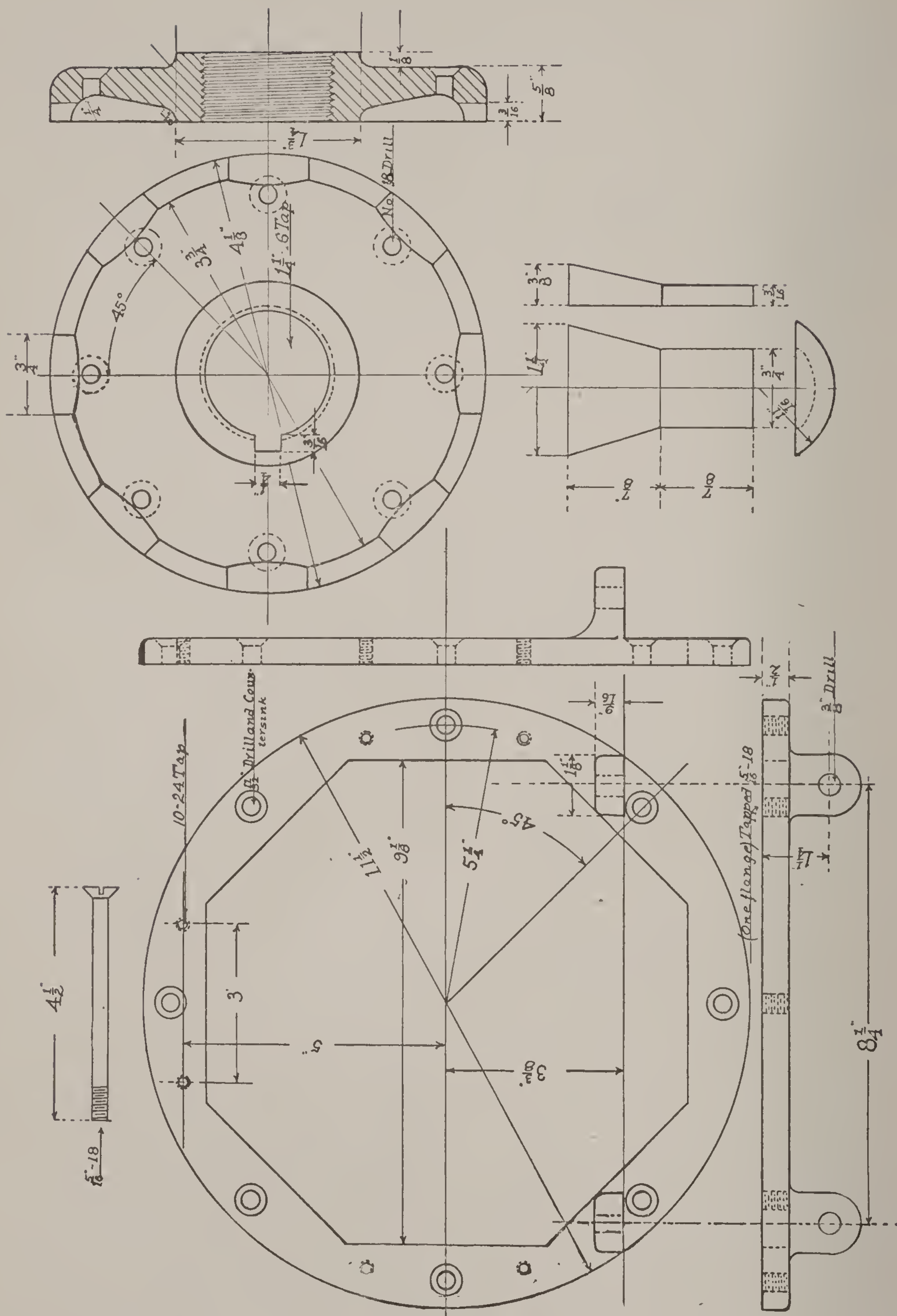

10-24 Tap
Drill and Countersink
(One flange) Tapped
Drill
No. 38 Drill
45°
45°

FIGURE 138.

the holes $\frac{5}{16}$ inch 18. Insert bolts in these holes, remove some of the clamps and drill two more holes and insert other screws, and so on until the whole eight are in place. Mark off carefully the location of the eight holes. Drill several $\frac{1}{4}$-inch holes through the sheets tangent to the narrowest portions of the flanges; insert a hack-saw blade and saw to the line of the pole pieces; then from the 6-inch center hole saw along the sides of the hole, leaving $1\frac{1}{8}$ inches wide. File off the burrs and round the corners. Set the field thus formed into the base, and adjust its position centrally by calipering from a temporary shaft laid in the bearings. The requisite amount to plane from the four lugs can then be determined. Clamp the field in its correct location, and drill $\frac{3}{8}$-inch holes through the lugs and into the base for a short distance. Remove the field, continue drilling $\frac{5}{16}$-inch diameter and tap $\frac{3}{8}$-inch 16. Replace and bolt the field, to the base by means of the $1\frac{1}{4}$ inch $\frac{3}{8}$-inch 16 hexagon cap screws. Lay a boring bar in the bearings and finish out the diameter of the fields to $6\frac{1}{16}$ inches. It will be necessary to clamp the sheets together at the ends of the poles, or the boring cutter will tear or bend the sheets.

Armature Shaft and Pulleys. Procure a suitable length of $1\frac{1}{4}$-inch diameter cold-rolled steel, and turn it, excepting the $4\frac{1}{4}$-central space, to $1\frac{1}{8}$ inch diameter. (See Figure 139.) On the ends of this space cut threads, 16 per inch, for a distance of $\frac{5}{8}$ inch. It is well to cut the keyway at this stage, in order that the slight springing caused by the planer tool may be eliminated by the subsequent lathe work. Let the keyway be $\frac{1}{4}$x$\frac{1}{8}$ inch and begin with the threads at one end and extend into the $1\frac{1}{8}$-inch portion about $\frac{3}{4}$ inch at the other. Turn the remainder of the shaft to the specified dimensions, fitting the $\frac{7}{8}$-

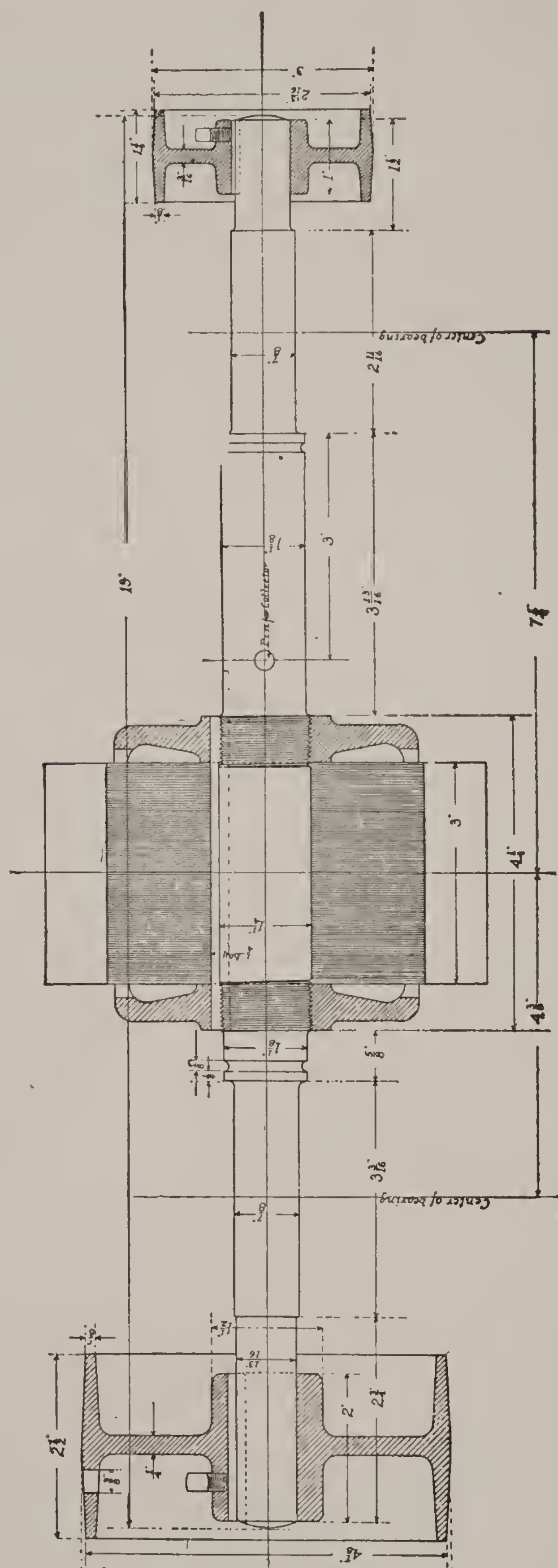


FIGURE 139.

inch diameters to the bearings. Sink a $\frac{1}{4}$-inch pin in the location shown for holding the collector. Two cast iron heads are to be screwed on the threaded portions of the shaft, the laminated core of the armature being clamped between them. A detail is shown in Figure 138. First, thread the castings to fit the shaft, and surface off the spots which are to press against the sheets. It will be noticed that the outer rim is not continuous, being gashed in eight places with crescent-shaped openings. Their purpose, along with the eight drilled and countersunk holes, will be explained in connection with the armature winding. Cut $\frac{1}{4}$x$\frac{3}{16}$-inch keyways across the threads. Screw one of these heads, or flanges on the shaft next to the collector end; match the keyways, and press in a $\frac{1}{4}$-inch square key, $4\frac{1}{4}$ inches long, as far as the end of the keyway in the $1\frac{1}{8}$-inch portion of the shaft.

If sheet iron for the armature core, as shown in Figure 137, cannot be procured, provide punchings 6 inches in diameter, with $1\frac{1}{4}$-inch hole, and $\frac{1}{4}$x$\frac{1}{8}$-inch keyway, Clamp a sufficient number to make 3 inches in thickness on a suitably keyed arbor, and mill or saw the eight slots. Slip the sheets on the shaft, with the slots in the same location as when milled; lay a tightly fitting bar in one of the slots to keep the end punchings from turning, and screw on the other head tightly; match the keyways, and drive the key back until its ends are flush with the hubs of the castings.

Put the core and shaft thus made, in a lathe and take a skimming cut across the sheets to remove the slight inequalities in the surface.

The pulleys are, as usual, of cast iron, but should be turned on the inside of the rims also, so as to be balanced. A

$\frac{1}{4}$-inch square key is needed for the main driving pulley, held in with a $\frac{1}{4}$-inch set-screw; but a round pin and $\frac{3}{16}$-inch screw will suffice for the exciter pulley.

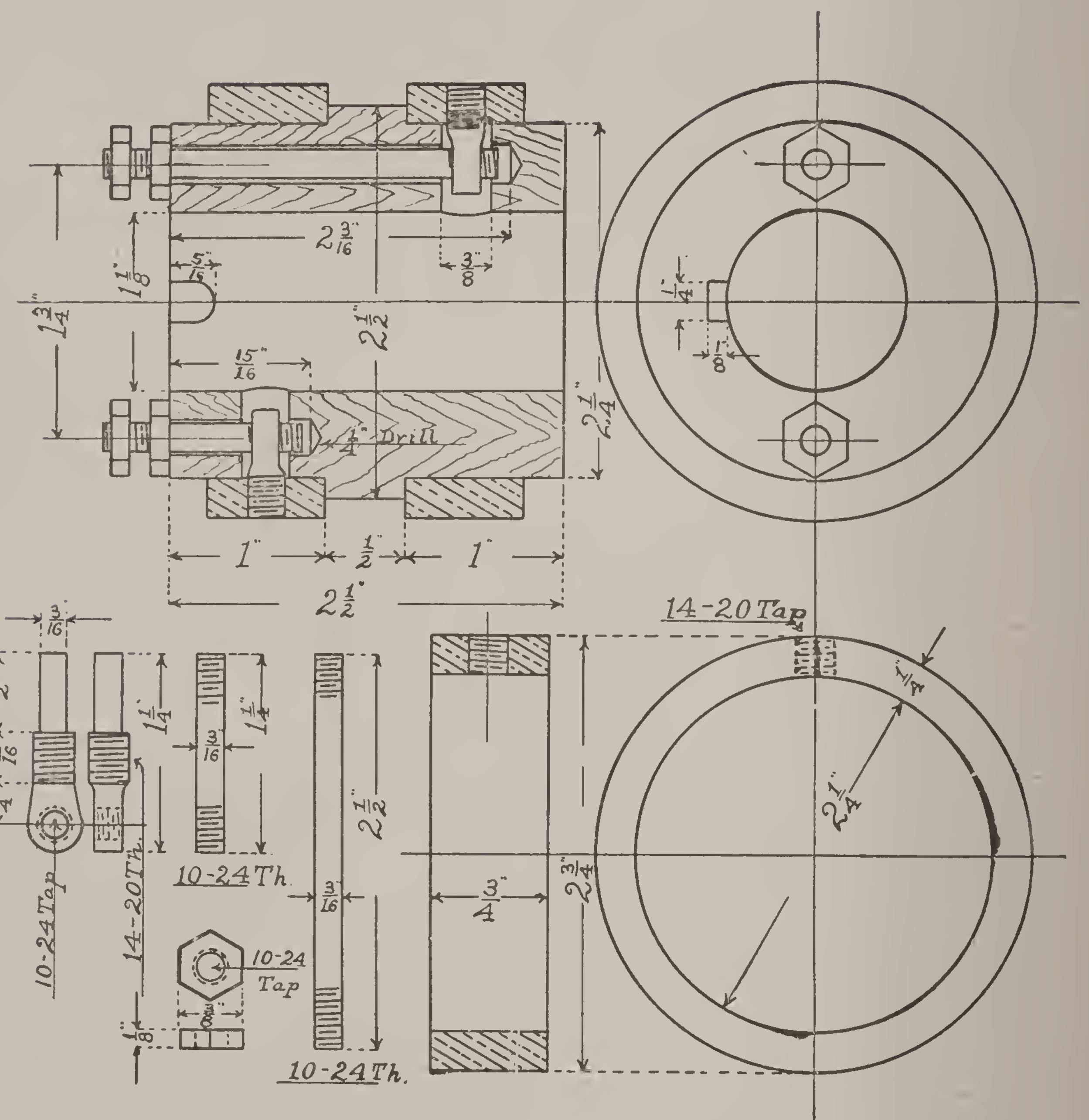


FIGURE 140.

Collector. This consists of two copper rings mounted on a wooden hub. Each ring represents a terminal of the armature winding. If seamless copper tubing cannot be procured, castings of gun metal may be substituted. Turn the rings smoothly and tap a hole with 14—20 threads in each.

Box-wood, lignum-vitæ or thoroughly seasoned maple will answer for the hub; but after turning and drilling it to the requisite dimensions, let it soak in melted paraffin for a few hours. Make two copper connectors, having the center portions threaded 14—20, one end turned to $\frac{3}{16}$ inch diameter, the other flattened and tapped 10—24. Press the rings on the hub, letting the tapped holes come over the $\frac{3}{8}$-inch holes drilled in the wood. Insert the connectors from the inside; the small ends will drop through the rings, and may be gripped with a hand-vice; screw the connectors tightly. Into them screw the long and short brass rods as shown, Figure 140. Solder-sweat the connectors into the rings.

Brushes, Holders and Studs. Copper brushes are commonly used on alternators; the continuity of the rings and the absence of sparking renders carbon brushes unnecessary. A brush and its holder is shown in Figure 141. Make the brush of thin leaf copper, cut in strips $3\frac{1}{2}$ inches long, $\frac{1}{2}$ inch wide, and built to a thickness of $\frac{3}{16}$ inch. Solder the sheets together at one end, and bevel the other to an angle of 45°. The holder is a brass casting, having a round hole to fit the stud, and a rectangular opening for the brush. In machining, do not saw the slot until after drilling and tapping. Thumb-screws are to be made from brass rod, and the presser shoe of sheet copper.

Two brass studs are required for supporting the brush holders. These, with their insulations, are shown in Figure 142. One is necessarily longer than the other. They may be made from brass rods or castings. Hard rubber is best for the washers and bushings. On reference to Figure 135 it will be seen that the cap on the smaller bearing has two lugs projecting from one end. These are to be drilled $\frac{5}{8}$ inch, and the surfaces faced true, and the studs attached.

Winding. As the machine is likely to be used either as a dynamo for supplying incandescent lamps, or as a motor on alternating currents, only one potential need be described, i. e., for

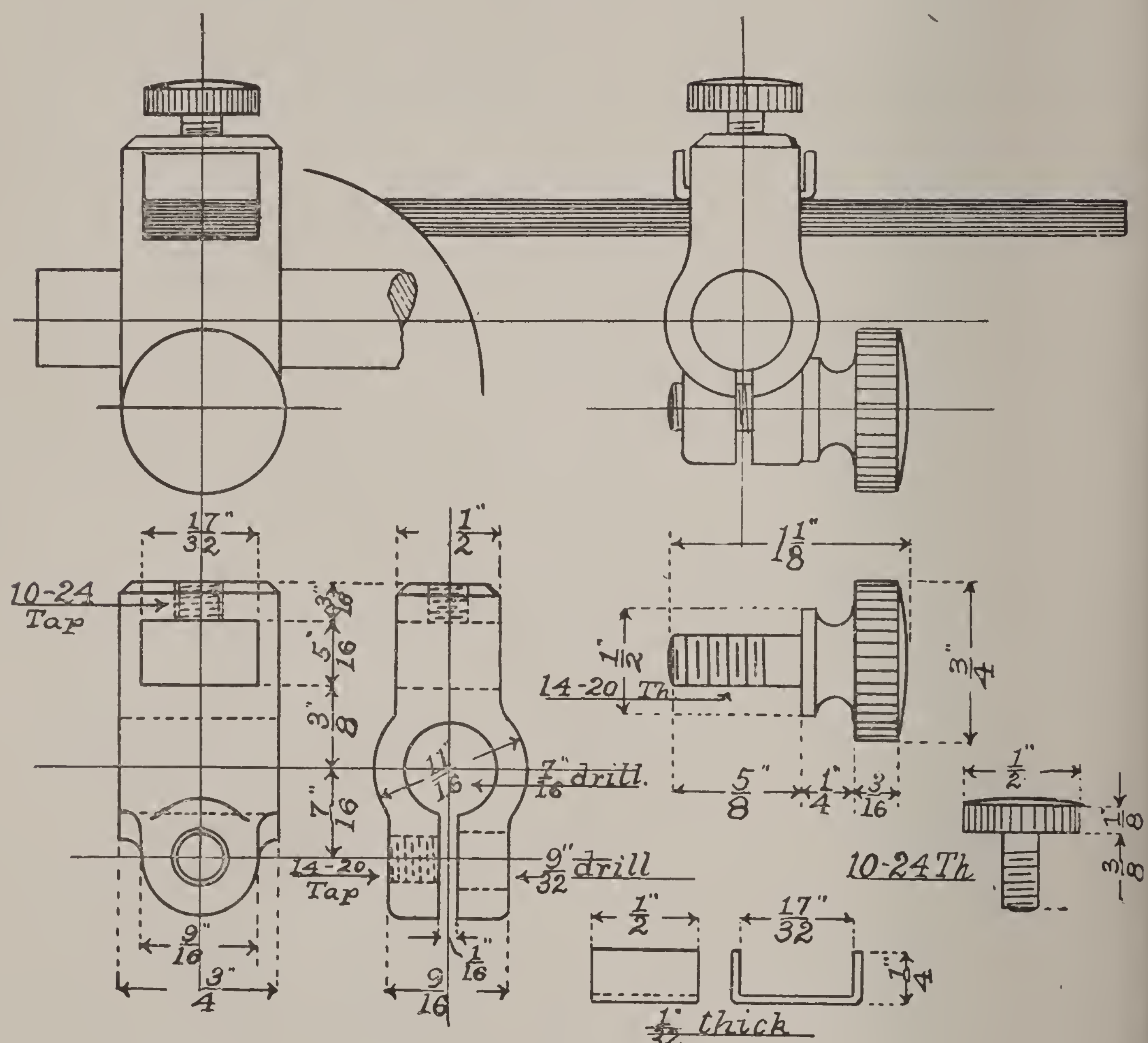


FIGURE 14-.

50 volts. For field excitation, however, it may be well to state several sizes in order that some dynamo already in the builder's possession may be utilized.

Eight field coils are required. They may conveniently be wound in the form shown in Figure 143. This is made of three

separate pieces of hard wood. Clamp the form to the face plate of a lathe by means of screws through the two $\frac{5}{16}$ inch holes. Wind a strip of thin paper $1\frac{3}{8}$ inches wide two layers deep around the neck of the form, but do not shellac it to the wood. Start the wire through the small hole, and wind one layer. Shellac it, and wrap on one thickness of thin paper; wind on a second layer of wire and stick on a second strip of paper, and so on until the form is full. As each layer is put on

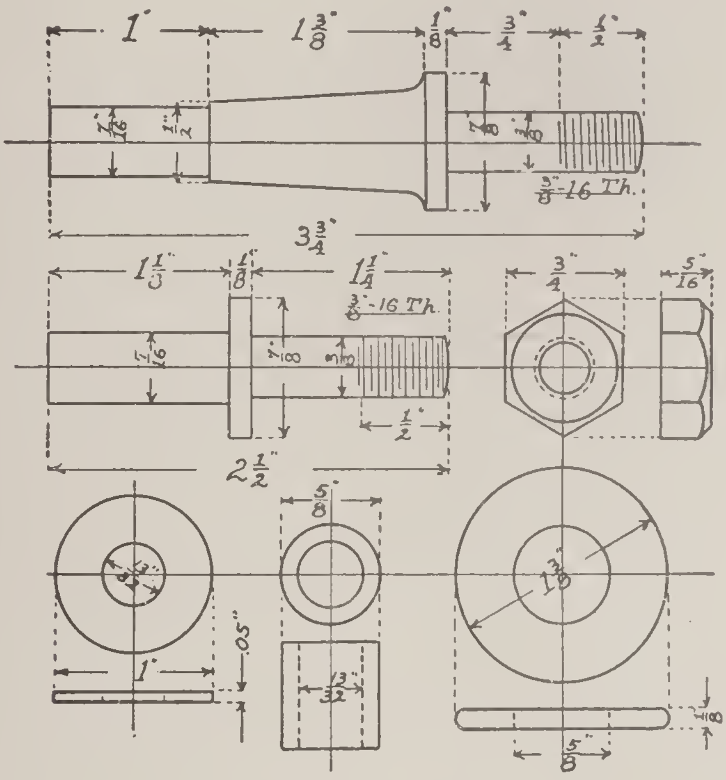


FIGURE 142.

hammer it flat, and see there are no gaps between the convolutions. When the shellac has dried on the outside layer, remove the bolts and separate the sides of the form from the coil; by running a thin case knife around close to the wood, the wire may be kept from getting deranged. Remove the center block. As the shellac on the interior layers will still be undried, lay the coil between two sheets of paper and put it under a few

pounds weight. In a few days, when thoroughly dry, tear off the superfluous paper, and, leaving the terminal wires on opposite sides, cover the coil with cotton tape. Immerse it in shellac for a few moments, and then when dried it is ready to be slipped on the pole piece. Care should be exercised to get the same number of turns in each of the eight coil in order that the field magnets may be uniformly magnetized.

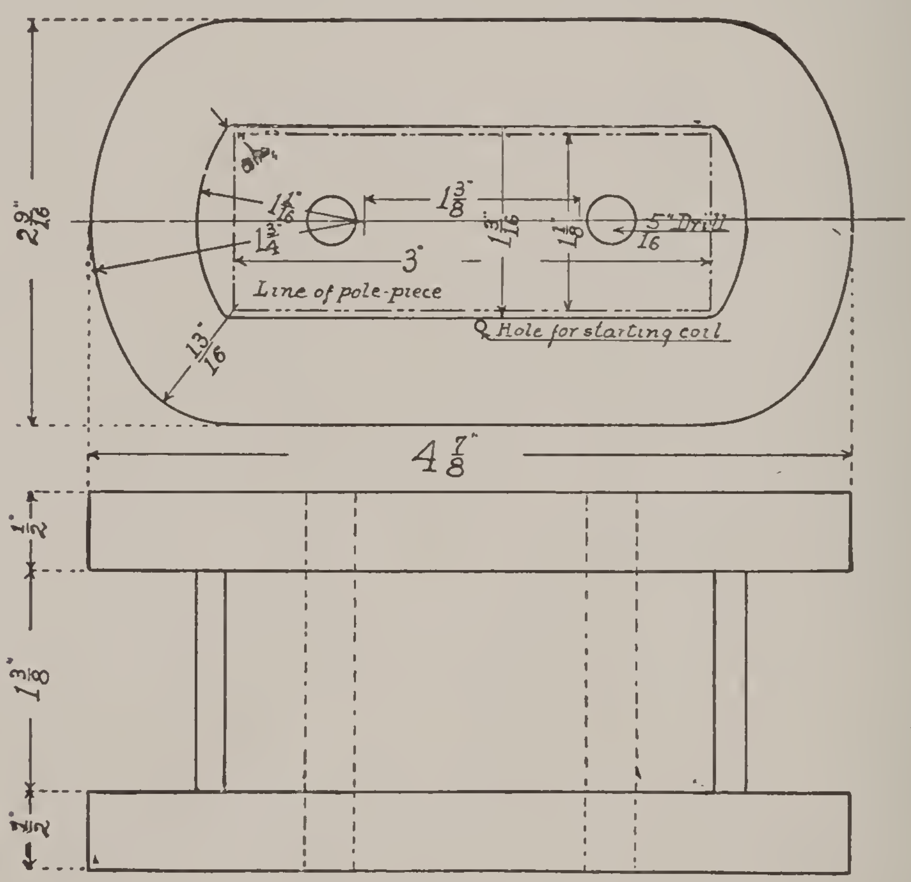


FIGURE 143.

The field winding should be, with an exciter giving 25 volts: No. 16 single cotton covered wire, each coil having 25 turns per layer and 10 layers. Total weight, 15 pounds.

Fifty volts: No. 19 single cotton covered wire, each coil having 34 turns per layer and 13 layers. Total weight 13 pounds.

One hundred and ten volts: No. 23 double cotton covered wire, each coil having 40 turns per layer and 16 layers.

Total weight 8 pounds. The 25 volt winding is preferable as the larger wire introduces a smaller proportionate amount of insulation, and allows a higher number of ampere turns than in the other cases, and the strength of the field largely determines the output of the dynamo. A device for holding the coils on the pole pieces is shown in Figure 145. Drill and tap a hole 8–32, $\frac{1}{4}$ inch deep on both sides of each pole, about $\frac{1}{4}$ inch distant from the cast-iron flange. Procure 16 strips of soft sheet brass 2 inch long, $\frac{1}{2}$ inch wide and $\frac{1}{16}$ inch thick. In one end drill $\frac{3}{16}$ inch holes, and attach the strips to the poles with $\frac{1}{4}$-8-32 iron round head screws. Slip the coils on the poles, drive tapering wooden wedges into the spaces at the ends of the coils, which will both serve to keep the coils from moving and to press the sheets of iron together. Now bend the brass strips over the wedges tightly against the coils. Between the coils and strips press bits of shellacked pasteboard or leatheroid to act as extra insulation.

Any potential, other then fifty volts, can be secured from the armature winding by using a proportionate number of turns of wire. To prepare the core, round the corners and shellac a layer of thin cotton cloth over every part of the sheet iron, and extending over on the cast iron heads for about $\frac{1}{2}$ inch. When dry, put on a layer of thin tough paper, then another layer of cloth, then paper, and so on until the insulation is nearly $\frac{1}{16}$ inch thick. Let each layer dry thoroughly before putting on the next, and make joints in successive layers in different places. Provide sixteen wooden wedges as shown in Figure 138. Make a radical slit through the insulation opposite the center of each of the armature projections, and press the wedges between the insulation and core for about two-thirds

14

their possible distance into the crescent shaped slots in the heads. Provide about 4 pounds of Number 9 (.114 inch dia.) double cotton covered magnet wire. Support the armature in a horizontal position and wind six turns around any one of the teeth; let the beginning of the wire be on the collector side, and draw each turn as tightly as possible. On account of the tapering

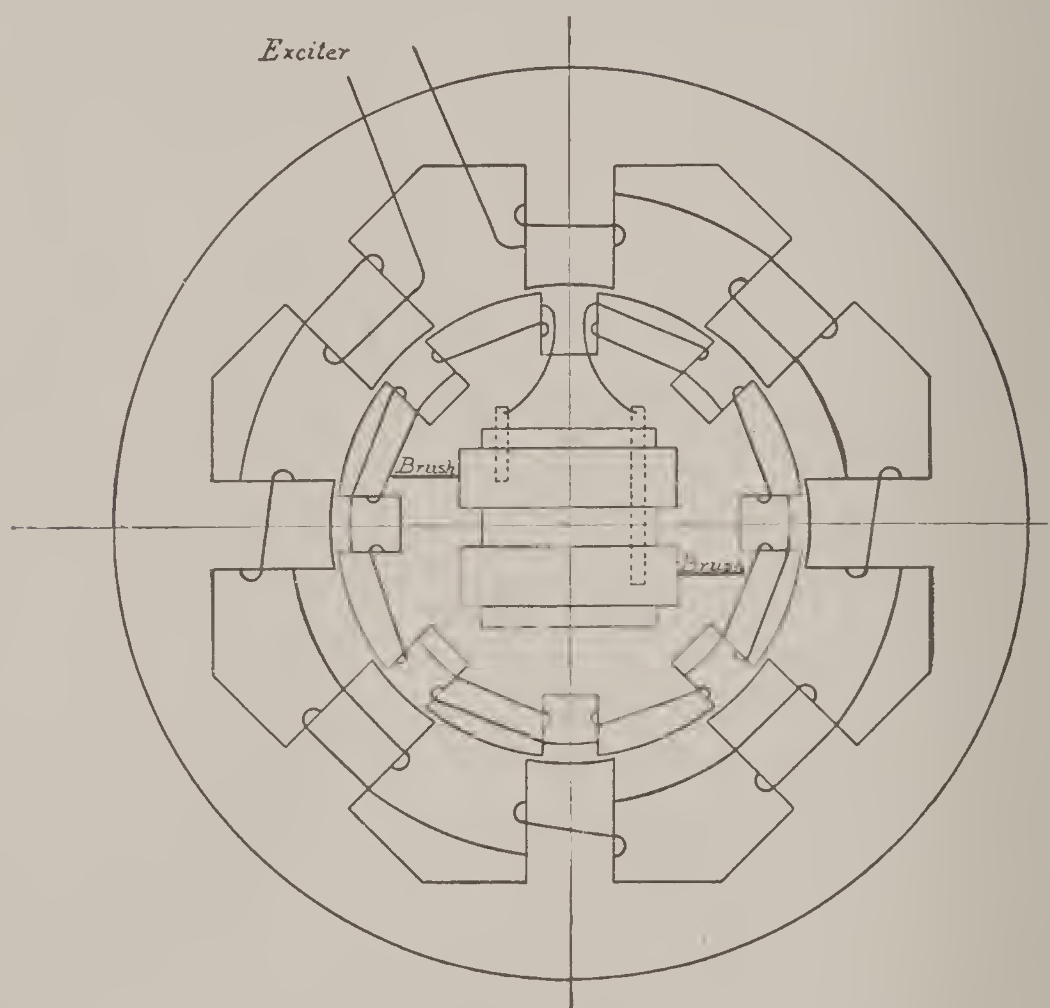


FIGURE 144.

sides of the projections the first turn will necessarily be at the bottom; the sixth will be near the top. Continue a second layer of six turns on top the first, returning to the starting point; do not cut the wire but wind twelve turns around the next projection in the opposite direction; then around the third wind in the same direction as on the first, and so on until the whole eight are

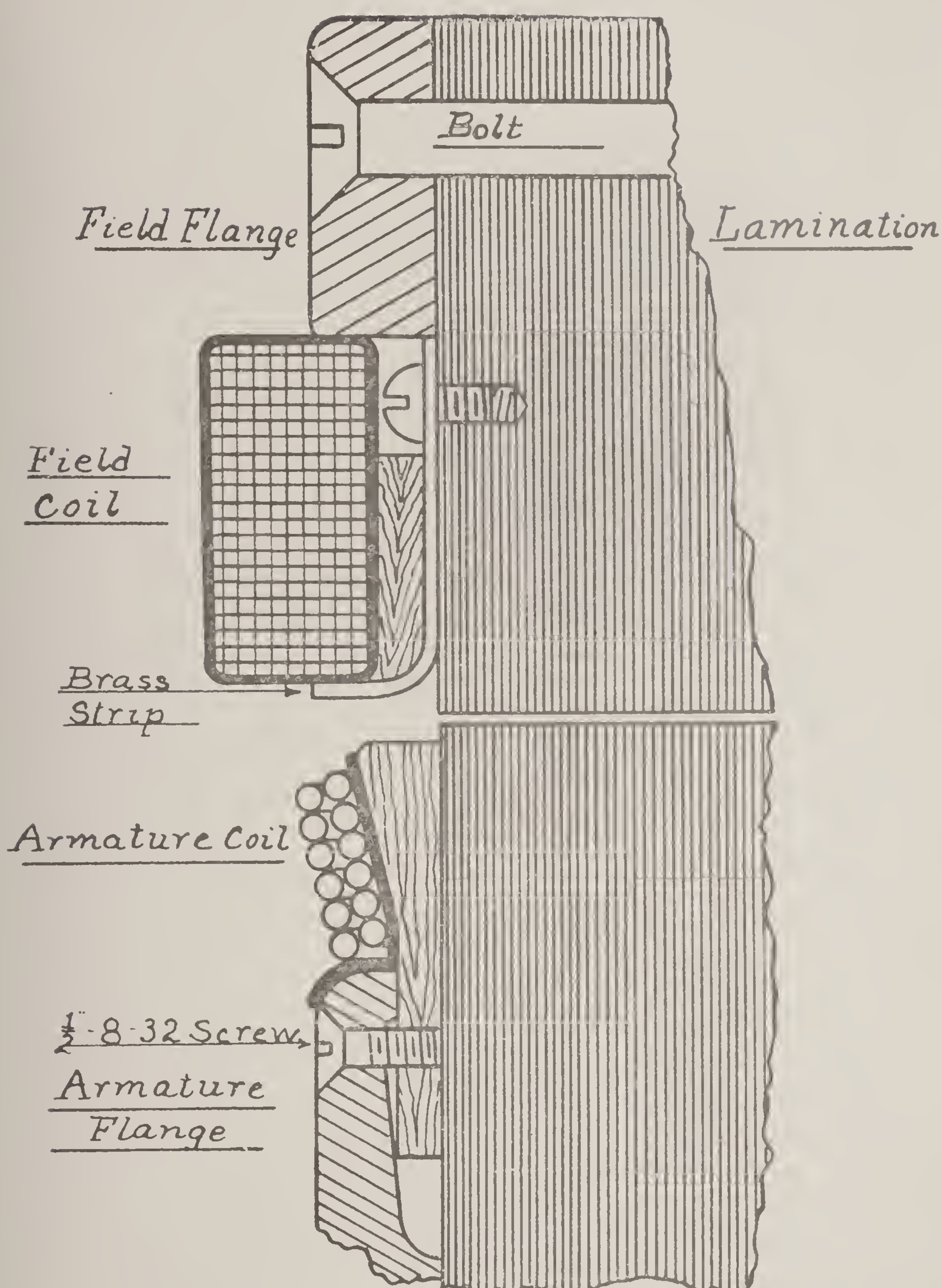

Bolt
Field Flange
Lamination
Field
Coil
Brass
Strip
Armature Coil
$\frac{1}{2}$"-8-32 Screw
Armature
Flange

FIGURE 145.

wound. The order in which they would then appear is shown in Figure 144. Make a number of thin tapering wedges of maple and drive them between the coils as shown in the end elevation of the dynamo, Figure 133, and more clearly in the larger view in Figure 137. Now drive the end wedges as far as possible into the heads; drill small holes opposite those already in the iron, and insert $\frac{1}{2}$ inch 8-32 flat head screws. Figure 145 shows this detail of fastening.

Remove all superfluous insulation from the surface of the core, and give the coils several coats of shellac. Lead the two terminal wires to opposite sides of the shaft, and bend them into small loops; cut off any extra length; slip the collector into place, and clamp these loops between the brass nuts and solder them to prevent loosening.

Connections. The method in which the armature has been wound provides for their proper connecting. The field coils must necessarily have been wound alike, and if similarly placed on the poles should be connected as follows:—Beginning at the upper left hand coil, (viewed from collector end), leave the outside end free, but connect the inner end with the inner of the next coil; then outer end with the outer end of the third coil, and so on, connecting inner to inner and outer to outer, until an outer end remains from the eighth coil, occupying the central upper position. The current should circulate in opposite directions around adjacent poles, so as to magnetize the iron in a regular succession of north and south poles. Send a current through the coils and test the polarities with a compass. Figure 144 shows the proper arrangement.

Three connection boards are provided. Their locations are clearly seen from reference to Figure 133. Details are shown in

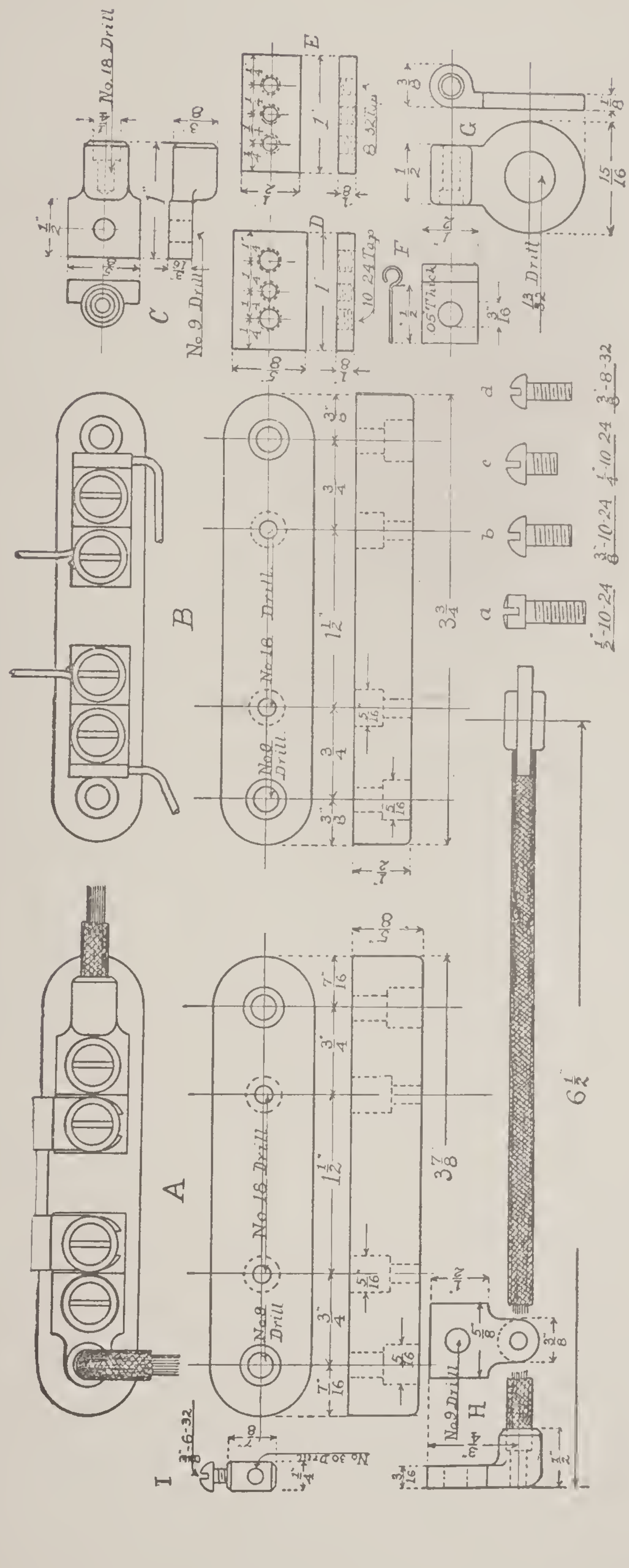


FIGURE 146.

Figure 146. *A* represents one for the main circuit, and *B* for the exciter circuit. Maple is good material for the bases, and the brass blocks are to be held by screws *d*, but the screws *b* and *c* enter the wood a short distance to keep the blocks from moving. Standard fuses of 20 amperes capacity should be connected in circuit. Those shown are soldered into copper clips, which in turn are clamped under the screw heads; good contact is thereby made, and ease of renewing secured. Screws *a* are for attaching the boards to the field magnet. The flexible cable should have a bundle of wires about $\frac{1}{8}$ inch diameter in all.

A device shown at *I* may be used to connect the ends of different field coils together; two wires may easily be held in each clamp. The field terminal wires are to be soldered into clips *F*, and attached to the brass blocks on the exciter board. Main circuit wires leading to the switch board or lamps should be soldered into clips *C*, but it will suffice to bend the exciter circuit wires around the screws.

Assembling and Using. Make sure that the electrical connections between the field coils are correct by sending the exciter current through and testing the polarities with a compass needle.

After once having bored the field central with the bearings, it should not be removed from the base. Screw the pulley-end pedestal, with cap removed, in the position determined by its dowel-pins. Insert the armature, and screw down the collector-end pedestal, not forgetting to slip the oil-rings on the shaft. Slide on the linings for the bearings, letting the slots for the oil-rings come uppermost. Place the caps on the pedestals, and adjust the linings length-wise, so that the armature and field match, yet allowance be made for an end motion of $\frac{1}{16}$ inch each way from the central position. Screw the caps down

tightly, and run a drill through the $\frac{3}{8}$-inch holes a short distance into the linings. Remove the caps and drive pieces of $\frac{3}{8}$-inch steel rod into the holes so as to be flush with the outside and project about $\frac{3}{16}$ inch inside. Complete the holes through the linings and replace them on the shaft. Fit the collector-end cap with its studs, insulations, cable terminals, brush holders and brushes, and replace it; also return the pulley-end cap to its place and put on the pulleys. Attach the remaining ends of the cables to the main connection boards; connect exciter and line. Fill the reservoirs in the pedestal with light oil. Slip on the belts and allow the armature to run at full speed—2000 revolutions per minute—half an hour or so before requiring it to generate, to make sure that the bearings are in good order.

If it is necessary at any time to remove the armature, it may be done as follows: Remove the pulleys and caps; withdraw the collector-end lining; the pedestal may now be lifted high enough to disengage the dowel pins and allow it to be removed from the base. The armature can now be taken out end-wise. By following this method, the pulley-end bearing need not be disturbed.

If pet-cocks have not been supplied, old oil may be withdrawn by removing the caps and inserting a siphon tube into the reservoirs.

Any reliable continuous current dynamo, of about $\frac{1}{8}$ horse-power out-put may be used for an exciter. If it be shunt or compound wound, the amount of current it supplies may be controlled by a rheostat inserted in the shunt circuit, but if it be series wound the rheostat must be so connected as to shunt a variable portion of the current into circuit without going around the field. Turn the main switch to have the lamps

connected, and allow such an amount of current from the exciter, that the lamps will burn to the required brilliancy. If the number of lamps is changed considerably, an adjustment of the exciting current will be necessary.

As a motor the machine is not self starting, unless some special devices, including a commutator, are introduced. Without such attachments, the armature must first be rotated at full speed before the main switch is closed. For ease it is well to have the field circuit also open. When a speed above "synchronism" has been reached, close the main and then the exciter switches, and the armature should immediately step into pace with the generator, and, within its capacity, run at a uniform speed independent of the load. A practical arrangement would be, to have the pulley on the main shaft, to which the motor is belted, held with a clutch. This pulley has, fastened to its spokes or hub, a smaller pulley which is belted to a larger wheel within reach from the floor. Turning this last with a crank, the armature may be easily driven at a high speed; then after the switches are closed, and the motor is seen to be running, throw the clutch that connects the load. The speed at which the motor will run will depend on the "frequency" of the alternations in the generator. With a frequency of 125 per second, the usual rate, the motor will turn 1875 revolutions per minute; with 133 cycles, the speed would be about 2000.

For economy an ammeter should be inserted in the alternating current circuit, and after the load has been attached vary the amount of exciting current until that absorbed by the armature of the motor is a minimum. Use a thin pliable belt, and, if possible, let it run in a horizontal position.

CHAPTER XIV.

TYPES OF COMMERCIAL DYNAMOS.

(DIRECT CURRENT.)

OF the many dynamos now in commercial use the author has selected those described on the following pages as standard kinds and best to use for examples of designs for description here.

They are divided into two classes: (1) the direct current dynamo; (2) the alternating current dynamo. As the difference between *alternating current* and *direct current* machines has already been discussed in previous chapters, it will not be here. In this chapter we will take up the direct current dynamos.

The Thomson-Houston Arc Dynamo, illustrated on page 219, is remarkable for its construction. It was designed by Professors Elihu Thomson and Edwin J. Houston, of Philadelphia. Originally its armature was nearly spherical and was wound with only three coils. The three coils were wound over the shell of the armature in three sets of windings, each layer being insulated from the shell and its neighbors. When the winding was completed the three ends of the free coils were carried through an opening in the shaft and attached to the three segments of the commutator. An illustration of the three part commutator is given in Figure 147. The field magnets are cup

shaped. They consist of two cast iron tubes, furnished at their inner ends with hollow cups cast in one with the tubes, and accurately turned to receive the armature.

Upon these tubes are wound the coils; afterwards the two magnets are united by means of a number of wrought iron bars which constitute the yoke of the magnet and at the same time protect the coils. The magnets are carried on a framework, which also supports the bearings for the armature shaft.

All late machines have ring armatures (see Figures 148-149-150), which are a great improvement over the old style (spherical armature) in the way of better ventilation, higher insulation,

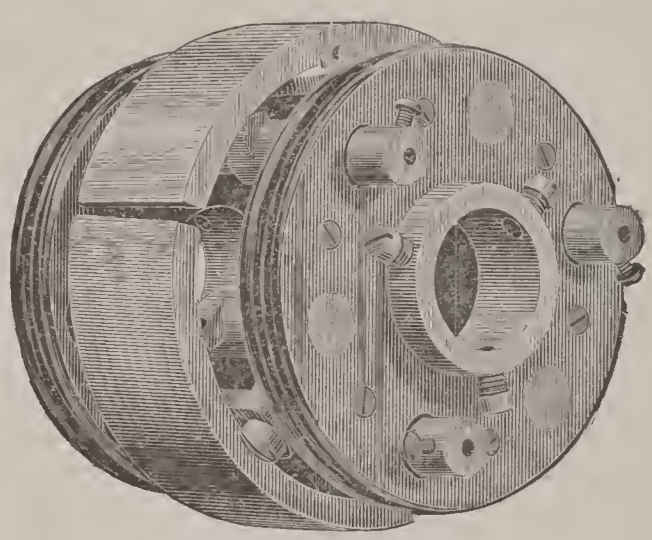
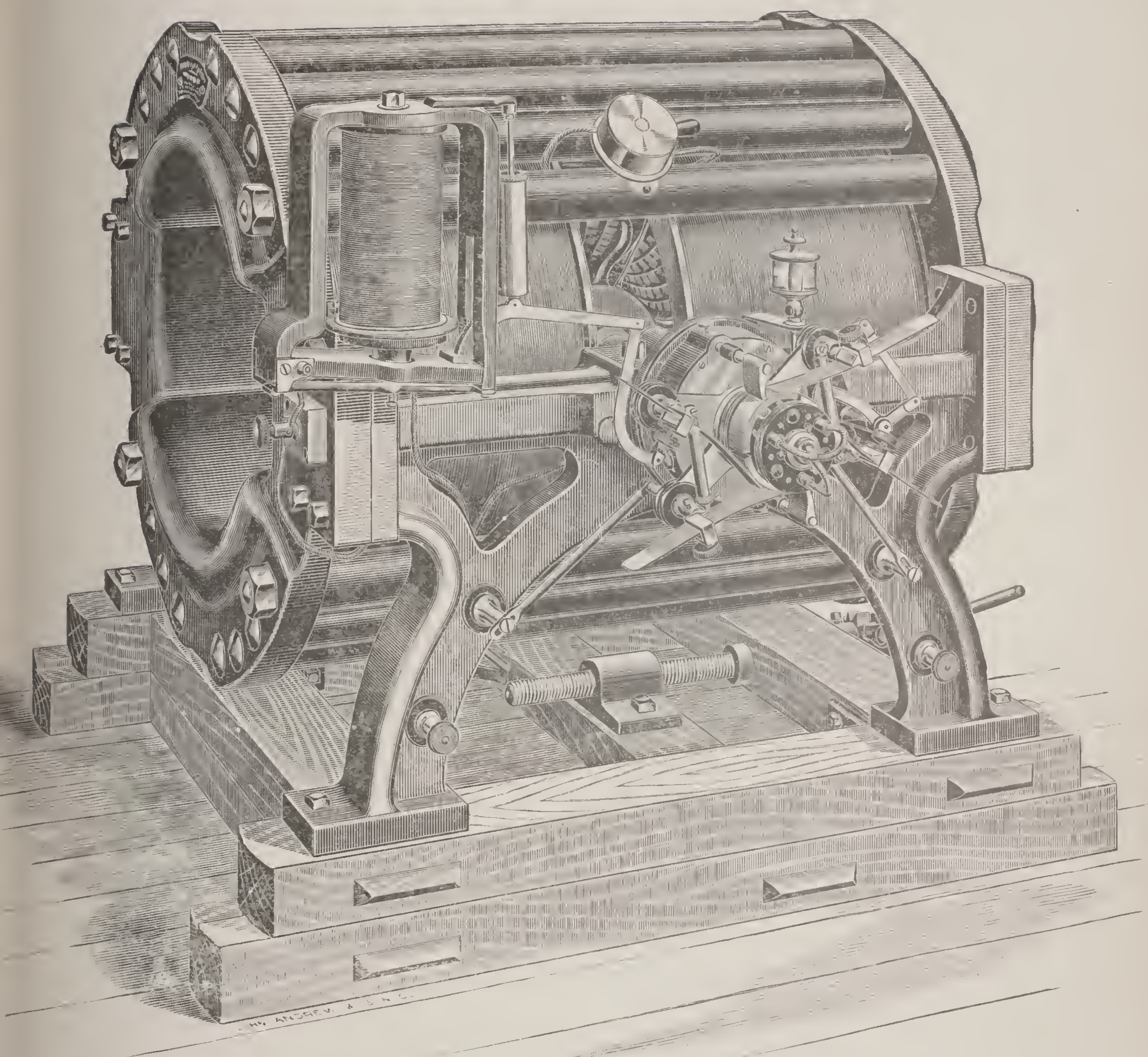


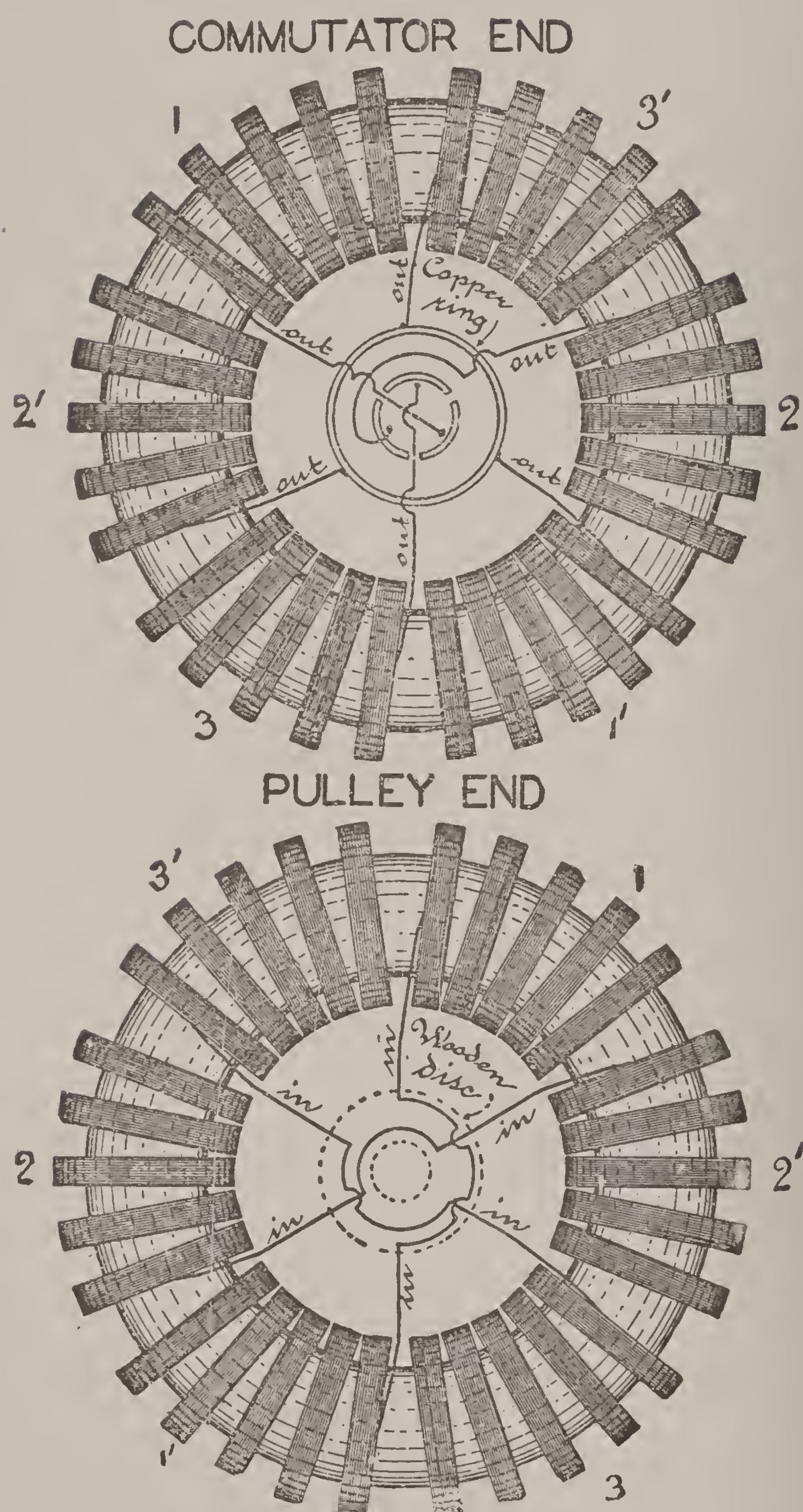
FIGURE 147.

greater freedom from burning out, and the ease with which faulty coils can be removed and new ones substituted.

These armatures are interchangeable with the old style armature, and can be used in any M. D. or L. D. machine. The commutator has only three segments in contact with which are four brushes. Regulation is obtained by an electro-magnet regulator, which controls the amount of current by automatic shifting of the brushes, in such a way that they short circuit one of the armature coils for a greater or less period of time, as the occa-



THOMSON-HOUSTON ARC DYNAMO.



FIGURES 148 AND 149.

sion may require, when from a reduction of resistance in the lamp circuit, by the extinguishing of a lamp, or otherwise, the current feeding the other lamps becomes liable to abnormal increase; this increase of current is made to flow through the coils of wire surrounding the iron core of the regulator magnet. The core becomes magnetized, causing the yoke to which the brushes are attached to be drawn up towards the regulator magnet, which changes the position of the brushes upon the commutator, so that they draw away from the maximum point, decreasing the potential; when more lights are turned on the

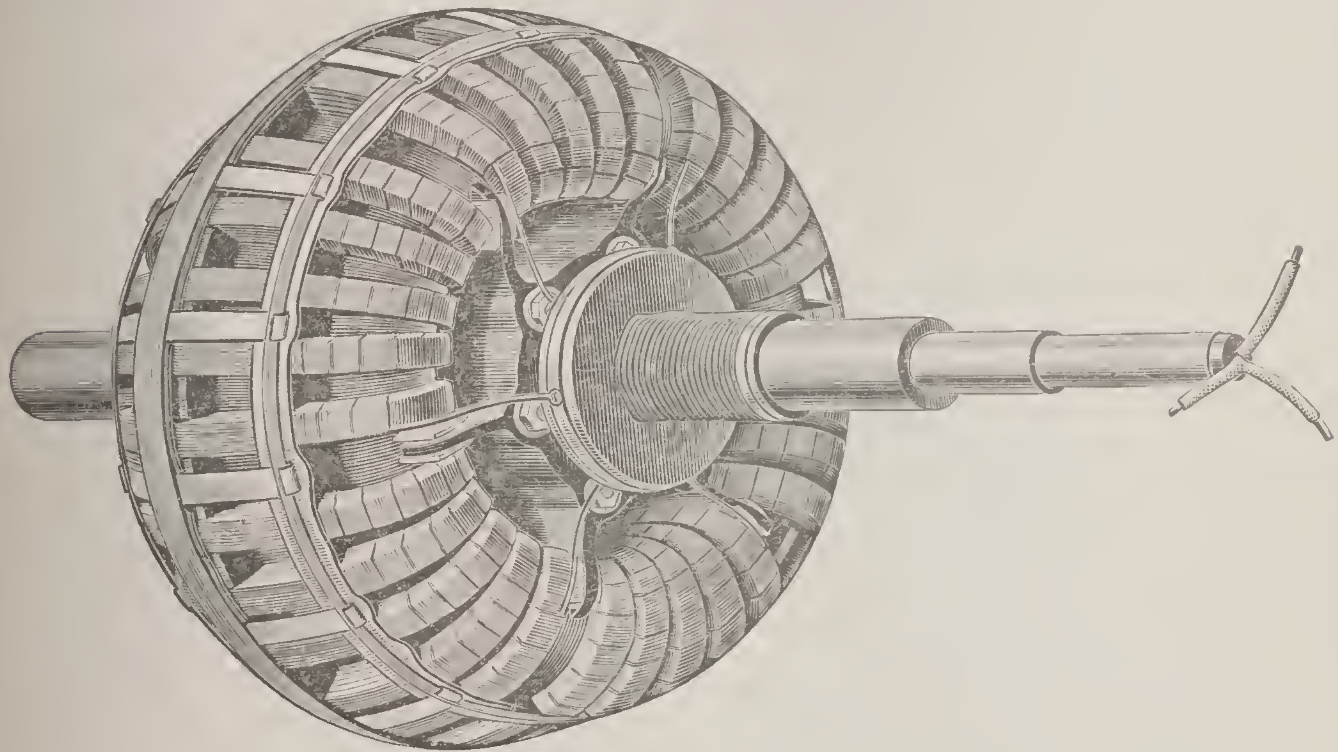


FIGURE 150.

reverse action takes place. The current governing the regulator is cut in and out by means of a pair of electro-magnets termed the controller magnets, and are connected with the regulator magnet of the dynamo. This controller, called a "wall controller," is shown in Figure 152.

Sparking at the commutator is reduced by a blower, being so placed that it sends a current of air directly on to the point

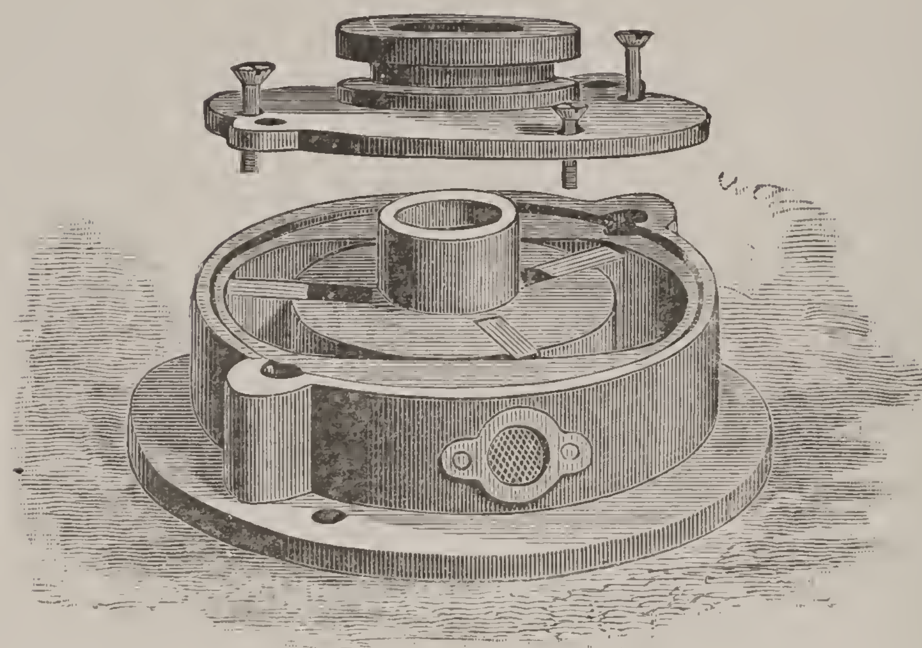


FIGURE 151.

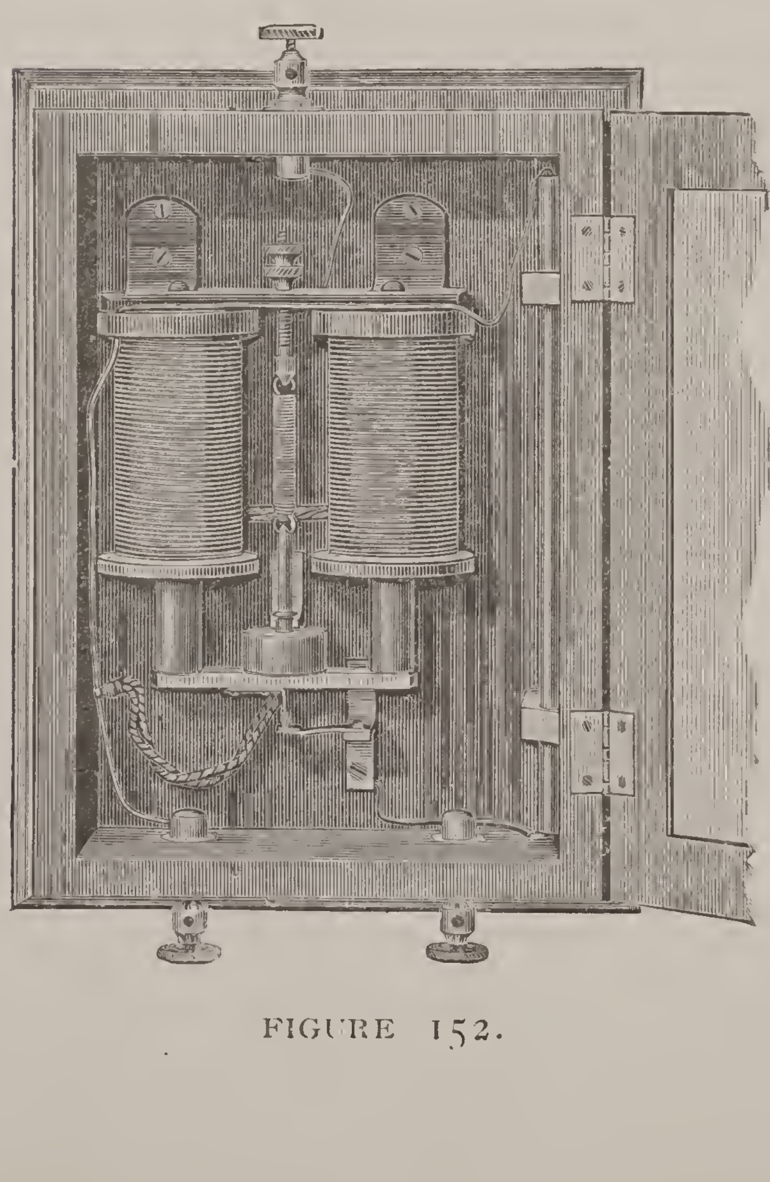


FIGURE 152.

of contact of the brushes and the commutator, which blows out the spark. An illustration of the Thomson blower is given in Figure 151. The largest machines have an electro-motive force of 3000 volts, and will maintain 63 arc lights in a single circuit. The ordinary machines, supplying 34 arc lamps at 45 to 46 volts each, with a current of 9.6 amperes, has an internal resistance of 10.5 ohms in the armature and 10.5 ohms in the field magnet.

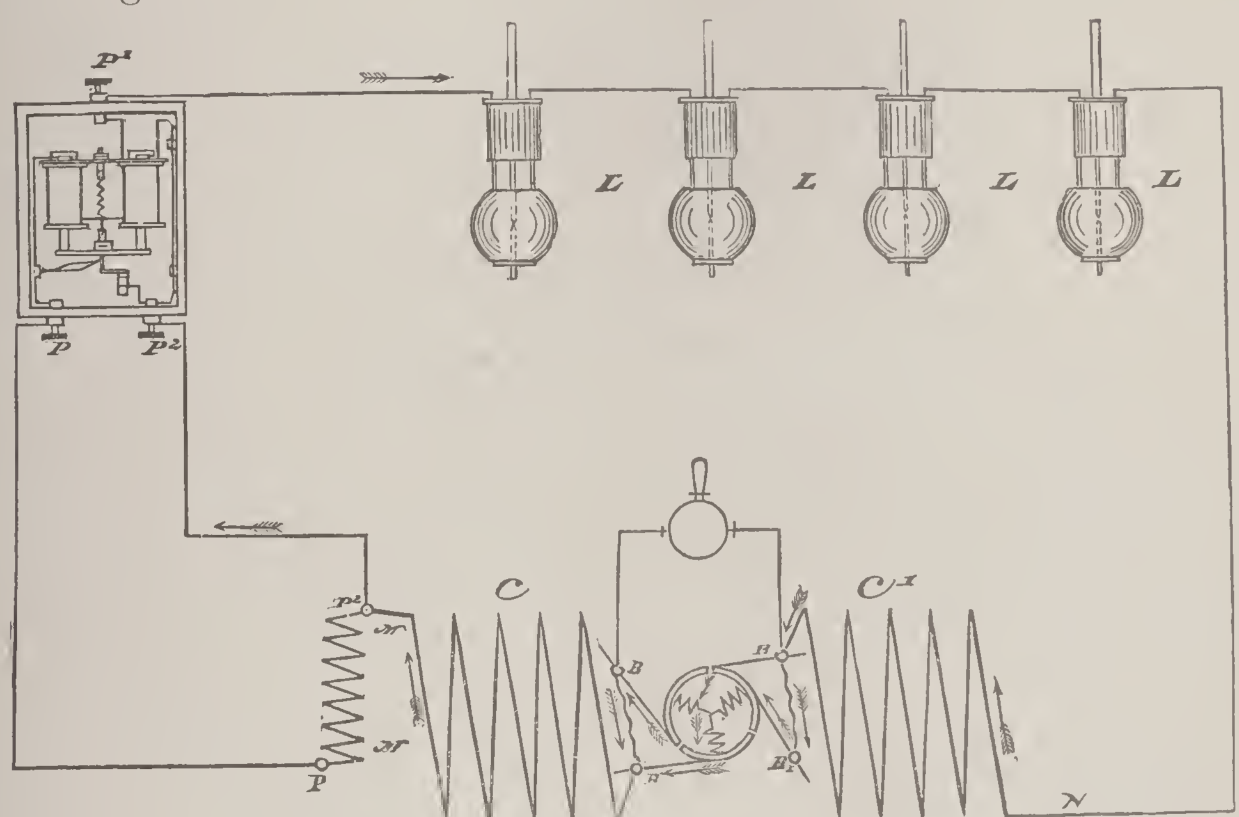
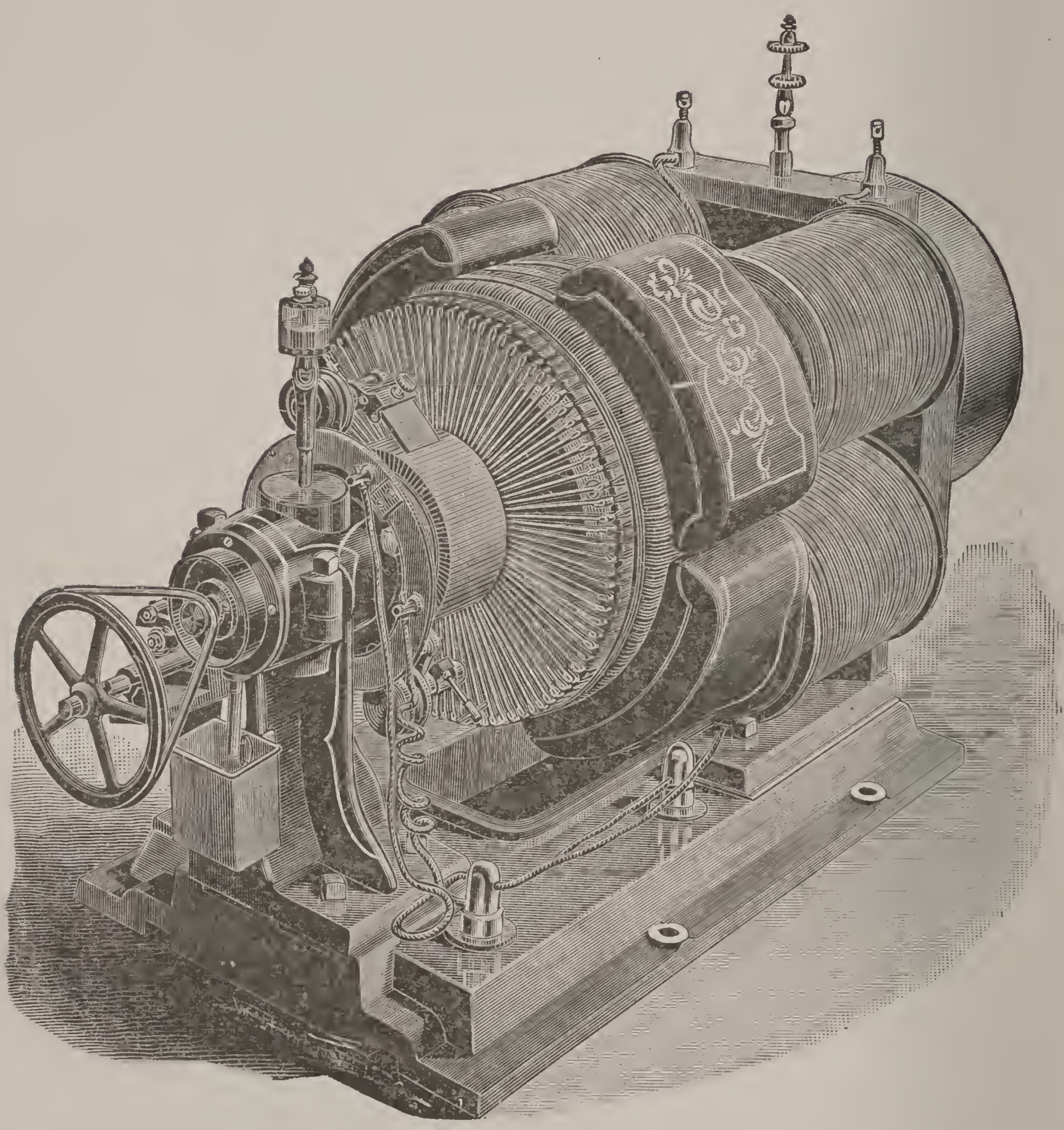


FIGURE 153.

A diagram of the complete arc circuit of this dynamo is given in Figure 153.

The Sperry Dynamo is illustrated in the engraving on page 224.

In an analysis of the Sperry generator it will be seen that the wire which is to revolve in the presence of the field magnets is placed at a good distance from the axis of rotation in such a manner that a high peripheral velocity is obtained with



THE SPERRY ARC LIGHT DYNAMO.

a comparatively low rate of revolution of the armature shaft, thereby wasting as little as possible in friction at the journals; and depreciation of the wearing parts of the machine is avoided. Secondly, the presenting the greatest possible percentage of this generating conductor to the magnetic masses or pole pieces of the field magnets compels the induction in the space occupied by the generating conductor to be the highest possible, and at the same time makes the resistance of the magnetic circuit of the machine the lowest possible.

The entire absence of overlapping of the coils is of great practical value. In case of injury sustained by one coil it will not cause the destruction of the whole armature, as the injured part can easily be removed and replaced without disturbing any other coil and without unwinding the whole armature down to this point, as in case of most forms of the cylindrical armature.

The leaving of the inside of the armature free to the pole pieces is valuable for ventilation, and in thus keeping the armature cool its electrical resistance is reduced and the danger of burning is avoided.

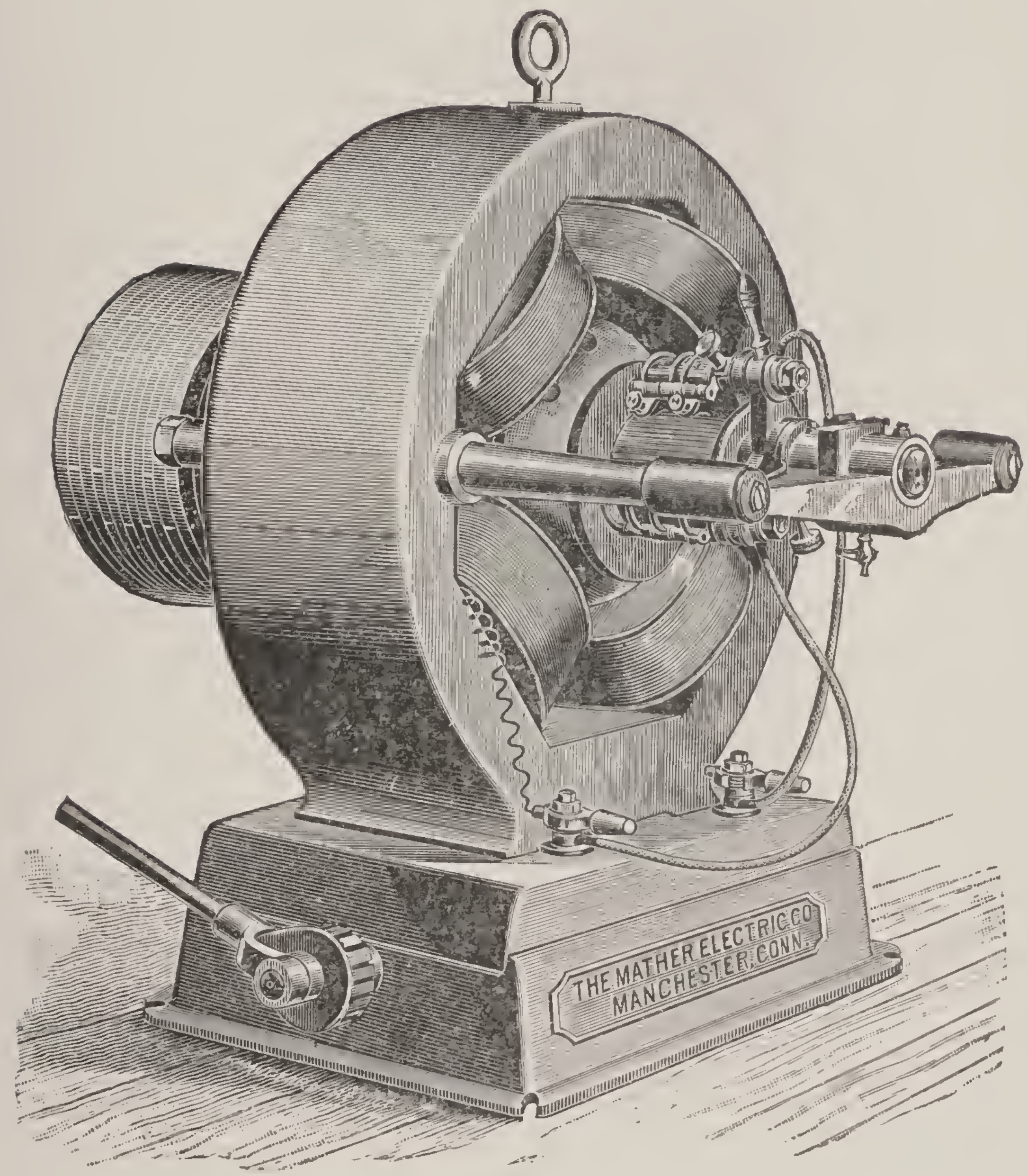
The dynamos are so constructed as to be operated several in series upon a single circuit. This greatly reduces the expenses of construction, as modern practice in insulation admits of high electromotive forces being employed. The total electromotive force upon the line being generated at several points is considered more reliable than when generated within the terminals of a single machine.

The plates of the armature core are made of thin iron, well annealed, and each carefully insulated from the other, and the whole mass supported by bolts which project from the edge and which are used to support the whole to the gun metal spider by means of which it is mounted upon the armature shaft.

The armature is covered with a coating of non-combustible and indestructible substance, the basis of which is asbestos. This substance has a very high insulating property, and cannot become charred by any temporary overload. The commutator is of the usual form, mica being employed as insulation throughout. It is very durable and of simple construction. The inventor claims that the brushes may be advanced from the position of full electro-motive force to even a position of zero voltage without sparking, the cross magnetizing action of the armature being small compared with the power of the field magnet.

The Mather Electric Railway Generator. Recognizing the demand for power transmission by means of the electric current, the Mather Electric Company has brought out a series of machines for that purpose. The generators are built up to 30,000, 50,000 and 75,000 watts, with four poles, and 180,000 watts with six poles. Drum armatures are used in all the machines. In the four-pole machines, the winding is such that the current has but two paths through the armature wires, and by a special method, devised by Prof. Anthony, no two wires having any great difference of potential are brought near each-other. The illustration represents the 75,000-watt generator, showing the general character of all the four-pole machines, with the field magnet in one casting. In the 180,000-watt six-pole machine, the field magnet is cast in two halves, but divided through the middle of two opposite poles instead of across the magnetic circle.

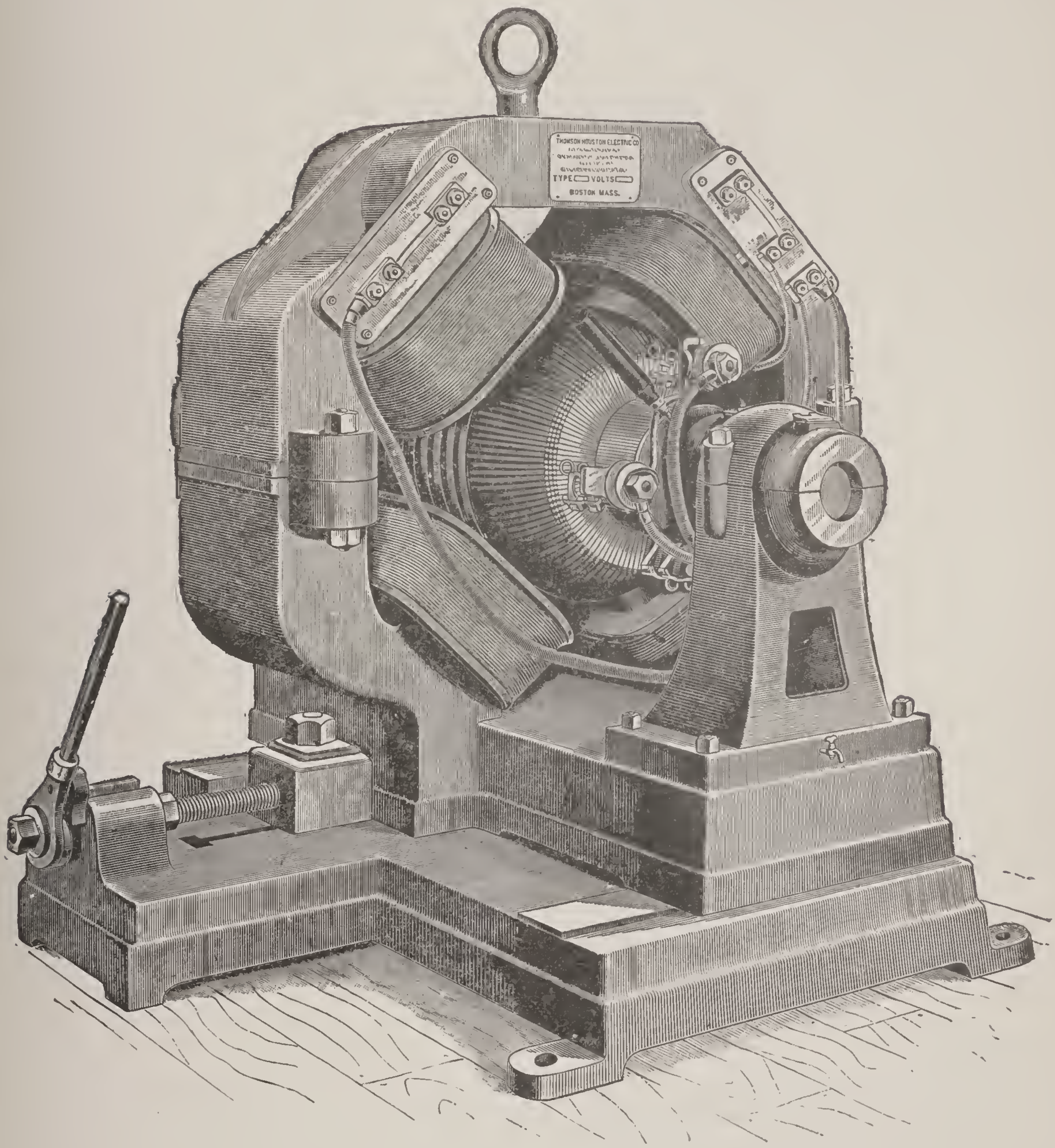
The Thomson-Houston 300-Horse-Power Generator. This is a multipolar dynamo—that is, it has four pole pieces, and has an output of 250,000 watts, which is equal to about 300 horse-power. The armature is of the Gramme ring pattern, and so



THE MATHER DYNAMO.

constructed that opportunity is afforded for the best insulation, and the danger due to great difference of potential between any two of its conductors is avoided. This is a most valuable and inportant feature, as in case of accident or injury to any coil, it can be easily repaired without affecting in any way the remaining coils. The construction of the armature affords excellent ventilation which is very necessary in dynamo machines, particularly as their size is increased, for the reason that the radiating surface does not increase in proportion to the size of the mass.

One of the most important features of this generator is the arrangement for lubrication and good alignment of the bearings. The boxes are made in two parts, and are entirely separate from the stands. On the top of the stand is a seat into which the spherical surface of the box fits, and in which the box is free to move. The bolts which secure it to the stand are smaller than the holes which are drilled through the box, so that a slight play of the box in the seat is permitted. The bearing shells or linings are removable, and are made in the following manner: A skeleton shell of brass is made, the interstices of which are filled with Magnolia metal. This is then bored and reamed to size, oilways being cut so that the oil circulation begins at the point where the oil rings touch the shaft. This method of manufacture permits of a perfect circulation of oil, ensures the cool running of the bearings, and greatly reduces the care and attention required by the dynamo when in operation. This type of box and bearing lining has proved so satisfactory that it is now being introduced in machines of smaller size, and will in future be used on all machines of large capacity. Whenever it is necessary to examine bearing linings, the armature is jacked up about $\frac{1}{16}$ of an inch, so that the bearing is relieved of its



THE THOMSON-HOUSTON 300-HORSE-POWER GENERATOR.

weight, two bolts removed from each stand, and the entire box taken out. In case it is not desired to remove the box, the cap can be taken off and the bearing linings readily removed.

The movement of the brushes is affected by means of the shaft on which a small worm is attached, and which in turn works in a rack fastened to the yoke. By means of this a very fine adjustment of the bearings can be made. The worm locks the yoke so that it cannot be removed except by hand.

In order that the conductors inside the armature may be held securely in place, an adjustable internal wire support has been designed. When the armature is being wound, the wires are forced into position so that they cannot sag, vibrate, or chafe the insulation. All tendency to short circuiting is thereby avoided, and the position of the wires assured.

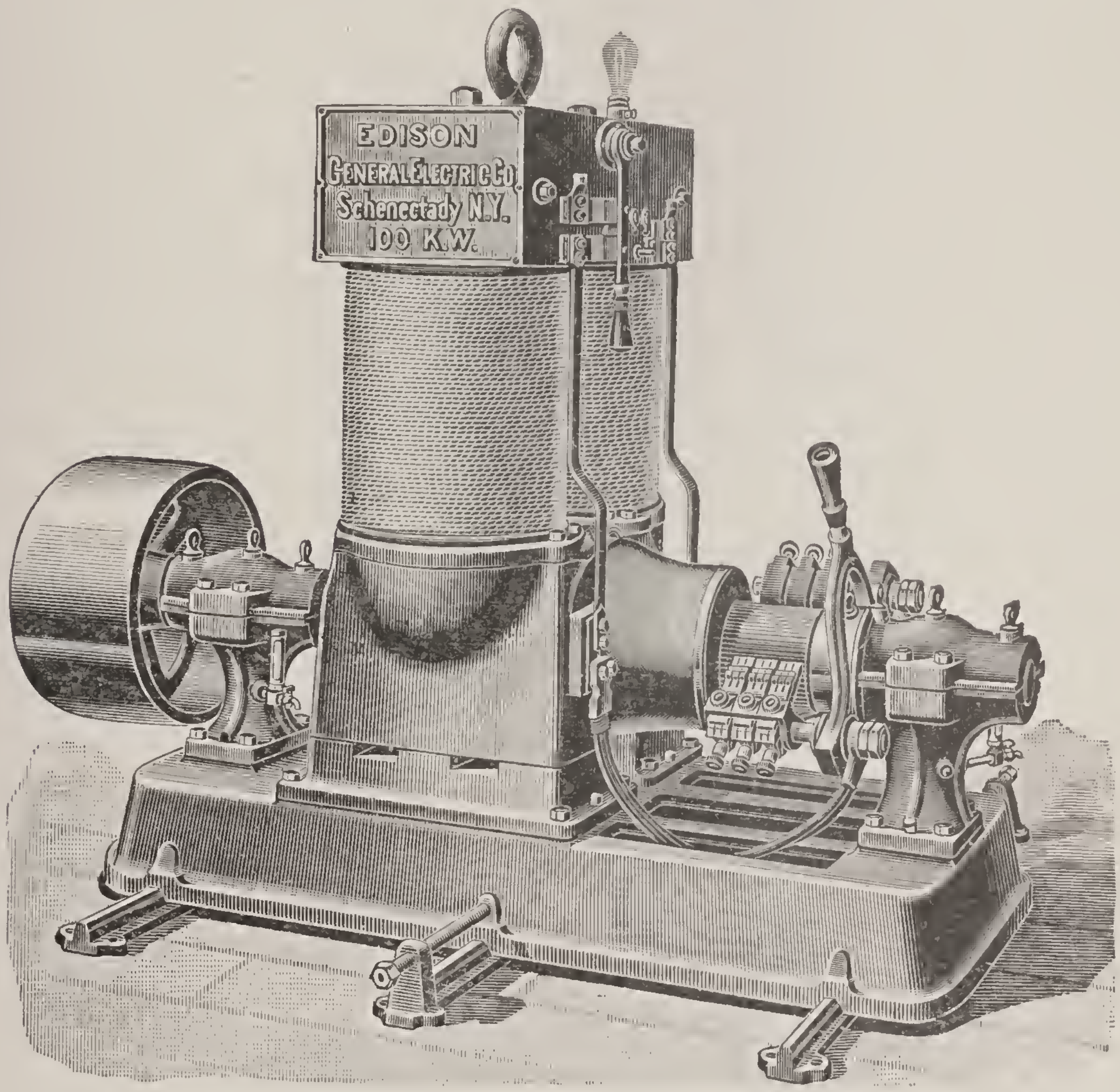
The commutator has 180 sections. In practice, the generator will have its fields separately excited, although the connection at the switch-board is so arranged that by throwing a switch the dynamo can be made self-exciting, should emergency require it.

The total floor space occupied by the 300-horse-power generator is 13 feet 3½ inches by 7 feet 1 inch. The height of the machine is a little less than 8 feet. The pulley is 43 inches in diameter, and has a 35-inch face. The speed is 400 revolutions per minute, and the dynamo, complete, weighs about 21 tons.

The Edison Direct Current Dynamo.—The field magnets consist of vertical cylinders with large wrought iron cores, which rest upon cast iron pole pieces and nearly enclose the armature. The armature is drum shaped. (See Figures 154 and 155.)

The core consists of a number of sheet iron discs, insulated from each other by sheets of thin paper. The core is mounted on an iron shaft, but insulated from it by an interior

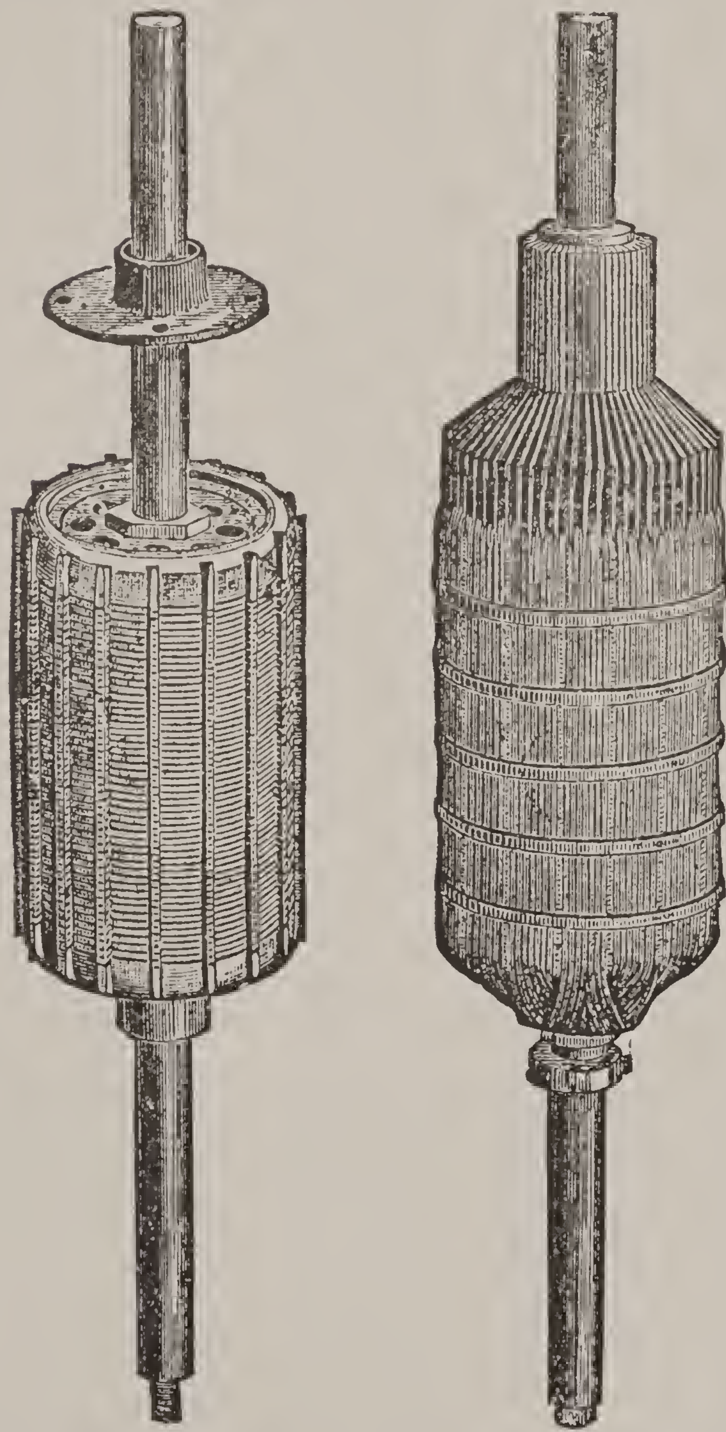
cylinder of lignum vitæ, while an external covering of paper insulates it from the coils. The coils consist of cotton covered copper wire, stretched longitudinally and grouped together in parallel, a number of wires in a group, all of the group being so connected as to form a continuous closed circuit. The groups



EDISON DIRECT CURRENT DYNAMO.

are arranged in concentric layers, and are of the same number as the segments of the commutator, the ends of the wires in each group being attached to arms connecting with the commutator segments, a spiral arrangement being adopted in making the connections between the straight portion of the wire and the

arms. The object of grouping is to secure flexibility for winding by the use of small wire and low electrical resistance, by having several wires in parallel, the effect as to the resistance being

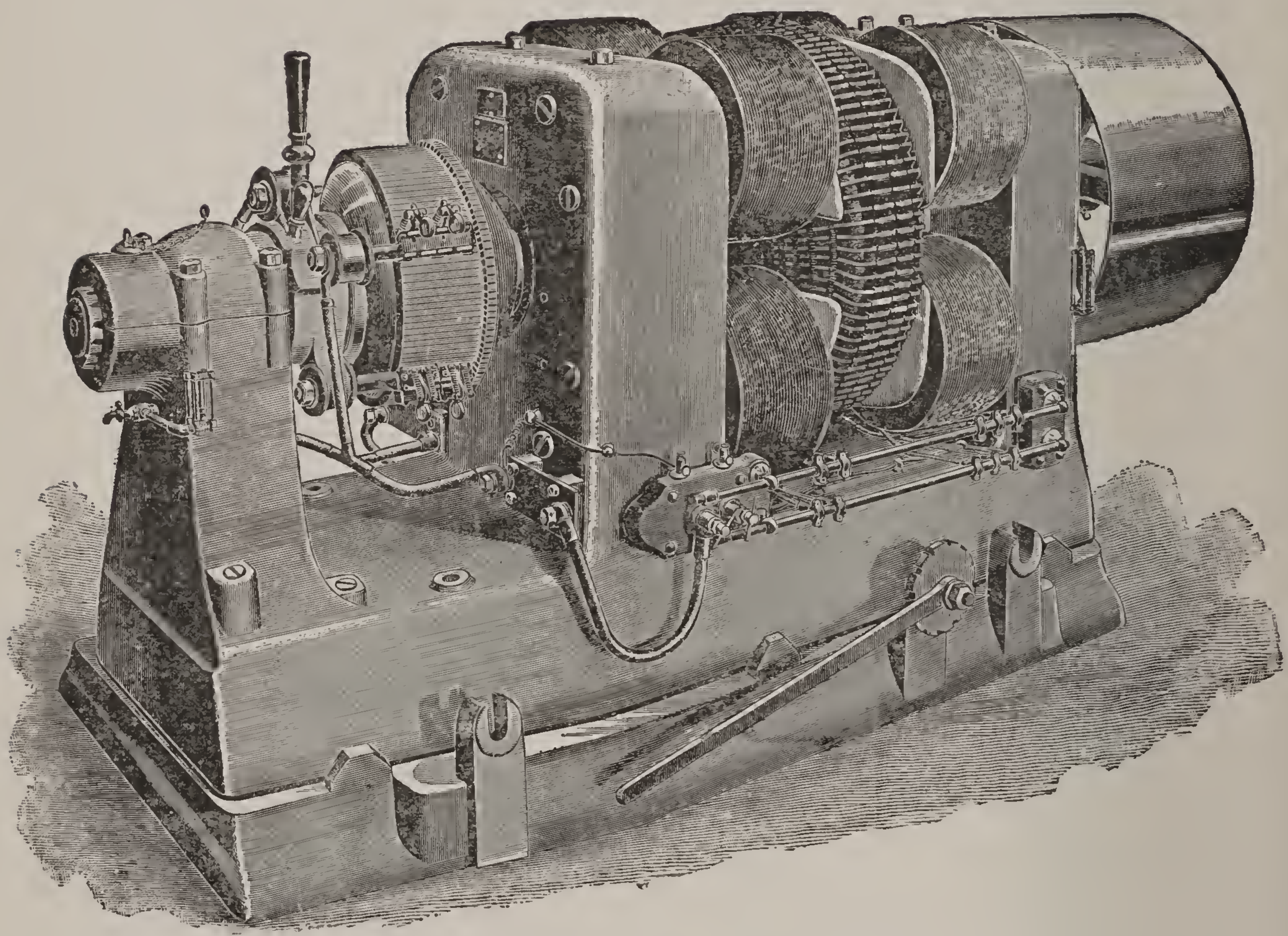


FIGURES 154 AND 155.

practically the same as if the several wires were combined in one. At the ends the wires are insulated from the core by discs of vulcanized fibre with projecting teeth. The discs of the cores are bolted together by insulated rods, and the coils are

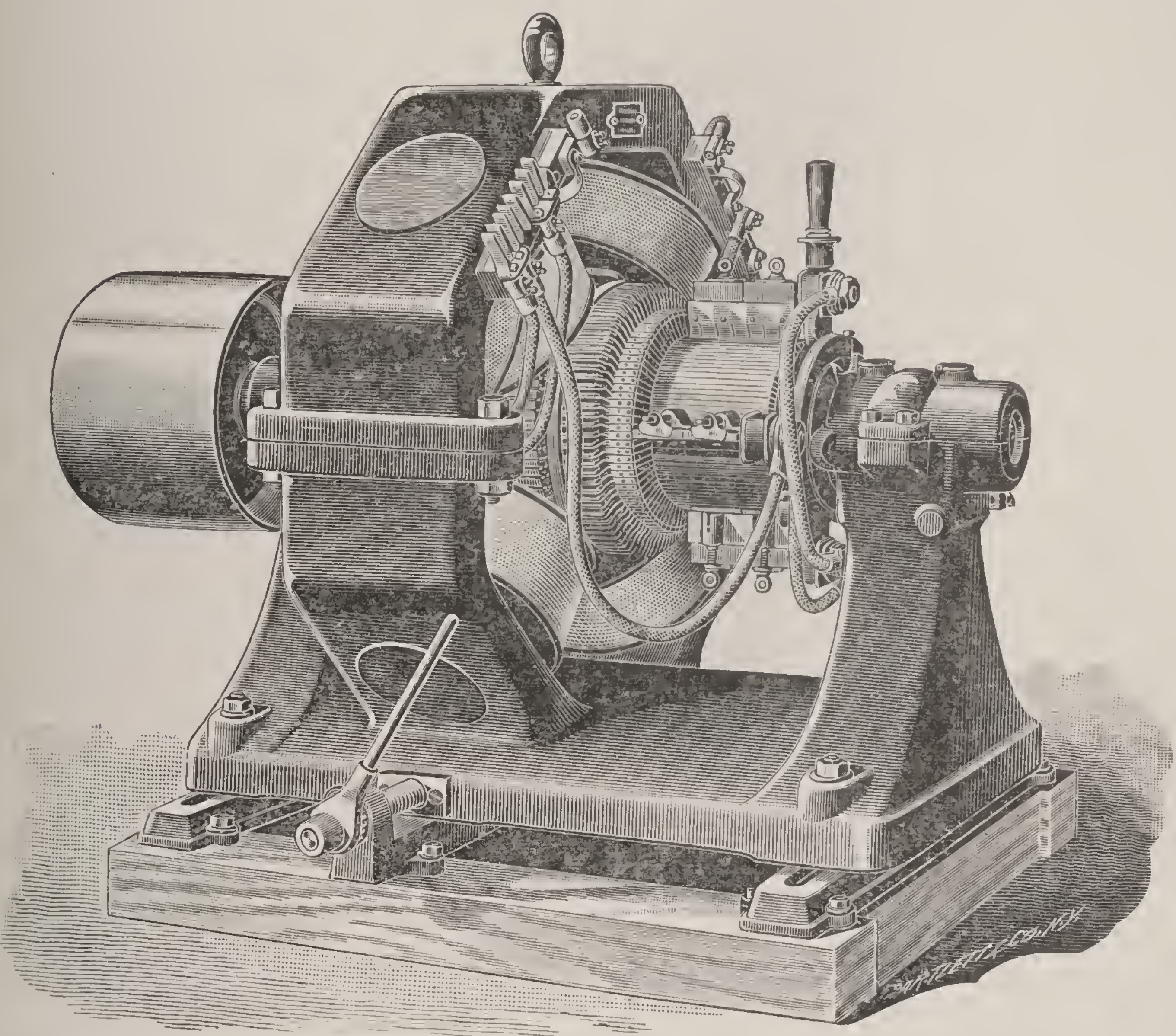
confined by brass bands surrounding the armature. The brushes are composed of several layers of copper wires, combined with flat copper strips, two layers of wire being placed between each two strips. This arrangement is to give a more perfect connection, and to prevent sparking by furnishing numerous points of contact, the copper strips confining the wire and making the brush more compact.

The Short Electric Railway Generator, which is shown in the accompanying illustration is a very massive machine of 150 H.P., and is capable of delivering a current of 225 amperes at a pressure of 500 volts. The field magnet frame is one large casting, weighing over 3000 pounds, of soft iron slowly annealed. To this are bolted eight field magnets, carrying the shunt and series coils, and provided with pole pieces of peculiar shape, arranged for side presentation to the armature. The armature of this generator possesses distinctive characteristics. It is of the Gramme ring construction. The massive spider carrying the foundation ring upon which the armature is built, is keyed to a shaft nine feet long and six inches in diameter. The armature core is formed of thin sheet iron wound spirally on the foundation. By this method of winding, each of the 200 coils is exposed to the air on all sides, thus receiving perfect ventilation. The diameter of the armature is 36 inches. Another feature is in the commutator box, where there is an adjustable ball-bearing thrust collar, containing several hundred balls, and so arranged as to carry the armature thrust in either direction without heating. The commutator has 200 segments, so that the pressure between adjacent segments is unusually small, and there is no sparking. There are four brushes, which are held together by two independent collars and sets of brush holders.



SHORT ELECTRIC RAILWAY GENERATOR.

Crocker-Wheeler Multipolar Dynamo.—In the multipolar type (illustrated) the steel magnets are turned to gauge and set into the yoke, the outer end of the holes for the fields being covered by a thin circular plate. The pillow block standards



CROCKER-WHEELER MULTIPOLAR DYNAMO.

are cast in one piece with the base, and the armature is rendered accessible by removing the caps of the bearings and the upper half of the magnet frame, thus permitting of the armature being lifted vertically out of the bearings, when the upper half of the magnet frame is thus removed. The rocker arm is

made in halves, held together by wing nuts, and travels upon a grooved ring attached to the pillow block standard, and slotted, the grooved ring being cut away through the upper side wide enough to permit the shaft to be lifted out. No solder is used in any part of these machines, and besides being built to stand 25 per cent. overload without undue heating, they will stand an altogether unusual degree of heating without injury.

The multipolar types above 25 H. P. (20 K. W.) for 110 volts have armature conductors of rectangular copper bars riveted together by means of strip copper and connectors, in place of the ordinary wire windings. These bars are insulated with mica and laid in slots in the armature core, so that they are pro-

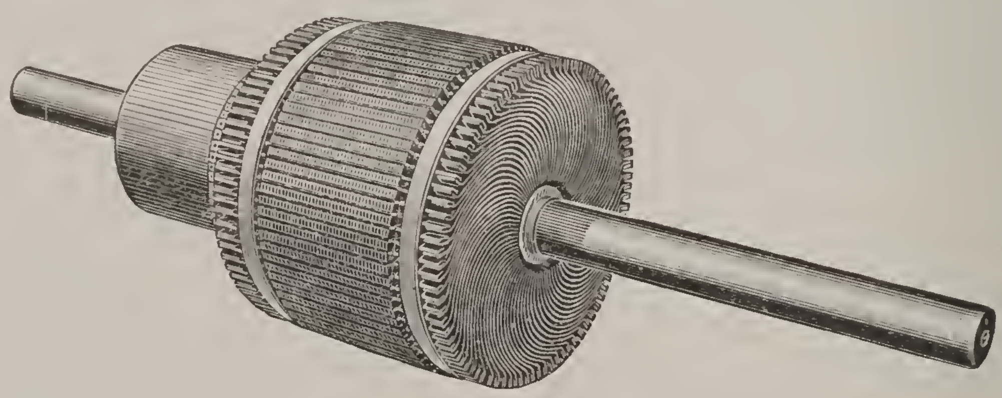


FIGURE 156.

tected from injury or displacement and are practically free from danger of a burn-out. The armatures thus wound, although for multipolar machines, have but two circuits, and may therefore be operated with one set of brushes instead of two sets, because of the novel "series grouping" of the armature winding. The common practice in multipolar armature winding heretofore employed renders one portion of the armature liable to short-circuit the other portions, if there is any inequality in the strength of the fields. This construction is an improved form of that formerly followed by the Standard Electric Co., of St. Johnsbury,

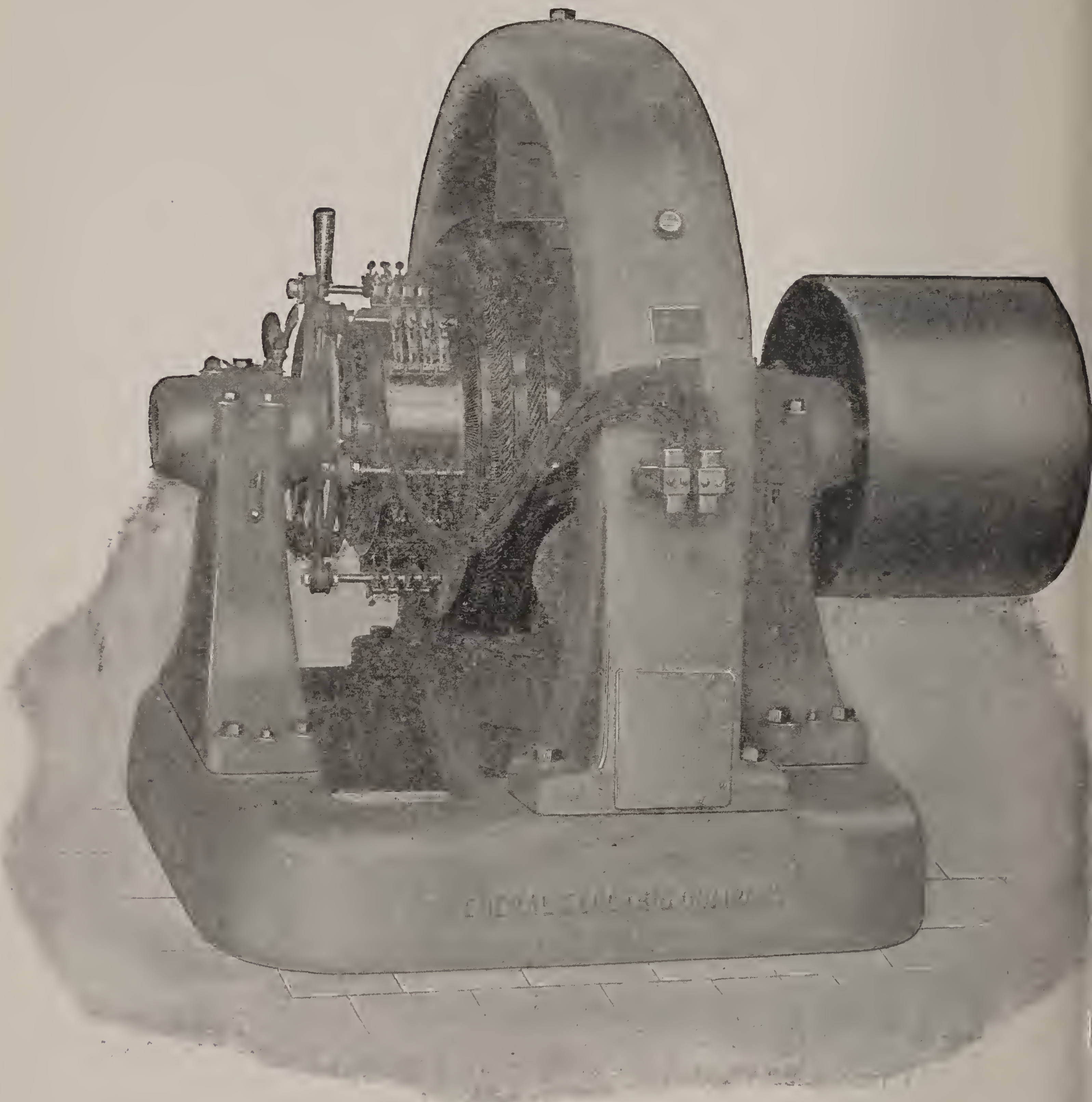
Vt., of whom the Crocker-Wheeler Company is the successor in this business. This form of armature was the invention of Mr. C. S. Bradley (see Figure 156), and was the prototype of all of the bar wound armatures now commonly made in large sizes, such as for railway generators, etc.

General Electric Company's 150 K. W. Belt Driven Railway Generator. — While the direct coupling of railway generators to their prime movers is recommended in all cases where prime movers of suitable speed can be obtained, certain instances arise where belted connection is admissible and commendable. Conditions which warrant the use of belted machines are found in connection with water wheels of exceptionally low speeds, or with engines already in service, but of too good a speed for the economical construction of direct driven generators.

The 100 K. W. and the 150 K. W. machines are made in the two-bearing form with the pulley overhung.

All railway generators are compound wound, the series coils being wound in one end of the spool, and the shunt coils in the other; so that either can be unwound without disturbing the other. The series coils are wound with flat copper ribbon, and are placed at the outer, or yoke, end of the spools; the shunt coils are of wire, and are placed at the inner, or pole face, end of the spools.

In machines which have a field winding of considerable depth, the winding is divided into two or more layers, separated by intervening air spaces, which extend through both the series and shunt portions of the completed coils and register with openings in the end flanges. The centrifugal action of the armature blows air



GENERAL ELECTRIC COMPANY'S 150 K. W. BELT DRIVEN RAILWAY GENERATOR.

through these intervening spaces, thus greatly increasing the cooling surface and reducing the temperature of the field windings.

The field spools are made up of sheet iron riveted to malleable iron flanges.

The armature is built up of sheet steel punchings or laminations, carefully annealed to reduce hysteresis, and japanned to insulate them from each other, and thereby cut down the Foucault current losses.

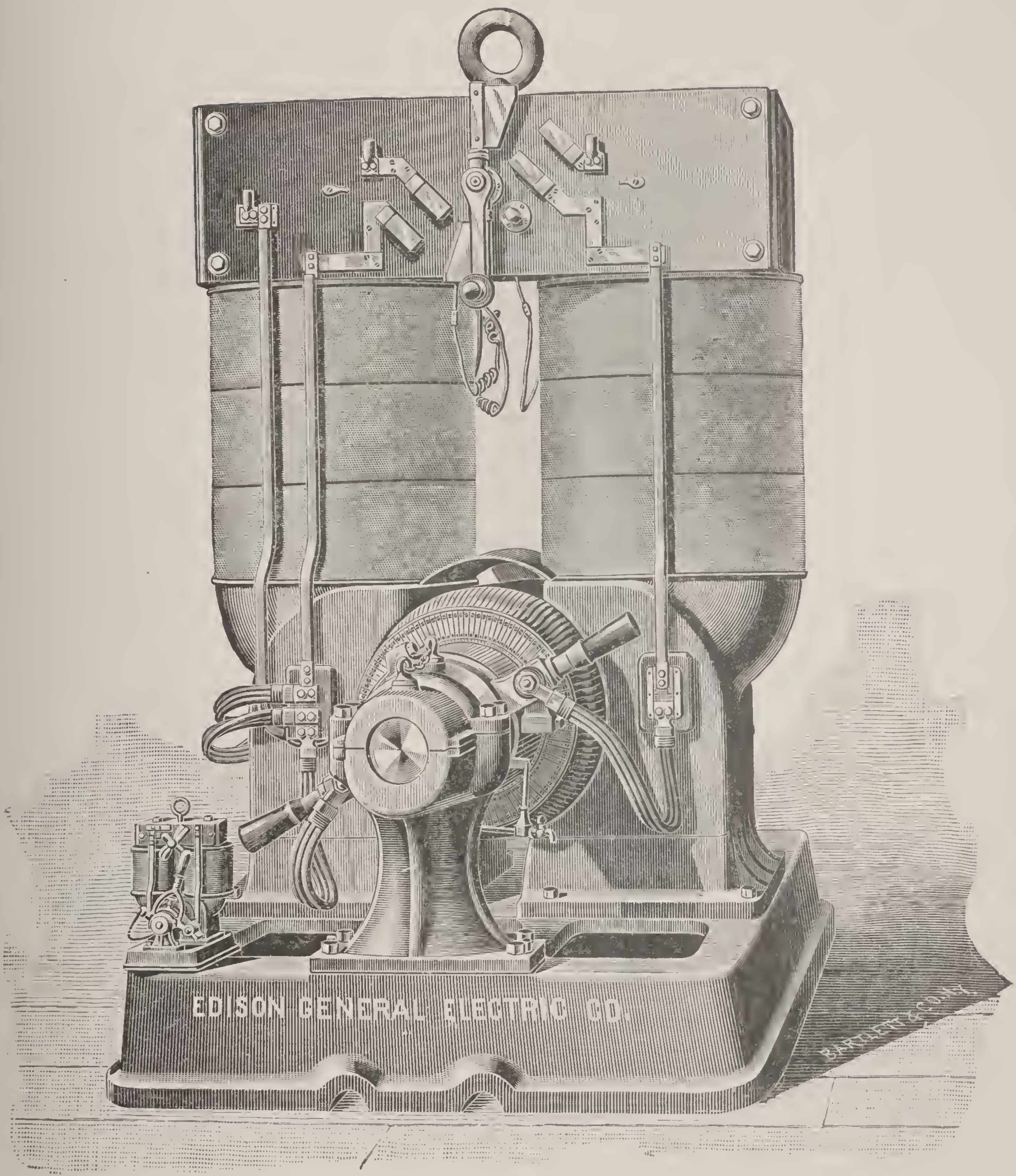
The laminations for all except the smallest machine are punched with dovetailed extensions, by which they are fastened in place on the cast iron spider. The laminations for the 100 K. W. machine are punched in one piece and keyed on to the shaft. At suitable intervals between laminations, space blocks are inserted, which are made up of steel strips set on edge and interlocked with the laminations. These radial steel strips act as the vanes of a centrifugal fan, drawing air from an opening within the spider, driving it through the core, across the armature coils, and into and around the field coils, thus ventilating and cooling all parts of the machine. The laminations are forced together by means of circular cast iron end flanges, which are suitably extended to support the end connections of the armature coils. These cast iron flanges are cut away to reduce the iron losses, which would otherwise be set up in them by the currents in the armature coils.

The armature coils are made up of copper ribbon, or bars, which are bent to shape before being insulated; they are then individually taped. Insulation is inserted between the several strips or ribbons forming one coil, and the whole is wrapped with varnished cambric. The coils are further insulated from the core by means of insulation laid in the slots.

The commutator construction is similar to that of the direct connected machines. A large number of segments per pole is used, and they are insulated from each other by mica of such thickness and softness that the commutator surface wears down uniformly.

The front end of the commutator is cut away, so that the face of the commutator can be turned off without interfering with an end flange. A solid clamping ring is used on all sizes made for belt driving, and the same design of clamping ring is used at both ends of the commutator, the two being drawn together by several bolts. The interior of the commutator is ventilated by air passing through the spider to the air ducts in the armature core.

Two Hundred Kilo-Watt Edison Generator. — In the accompanying illustration is shown the latest form of Edison railway generator of 200 kilo-watt capacity. As will be seen, it is of standard bipolar type, the general features of which are so well known as to need no further description. To adapt this generator to the demands of electric railway service, its field has been supplied with a compound winding, easily adjustable to meet the necessary requirements by means of a shunt coil, which is conveniently placed in the back board of the keeper. The close adjustment obtained by this arrangement greatly facilitates the operation of generators in parallel, and forms one of the characteristic features of this particular type. The series field is composed of sections wound on spools, which are slipped separately over the cores, and then properly connected. In the event of a fault occurring, the spool in which it develops can be removed and another substituted at once; this not only prevents delay, but makes any repairs necessary a matter of comparatively small expense. The armature is so wound that it has two distinct windings, and each end is furnished with its commutator, rocker-



TWO HUNDRED KILO-WATT EDISON GENERATOR.

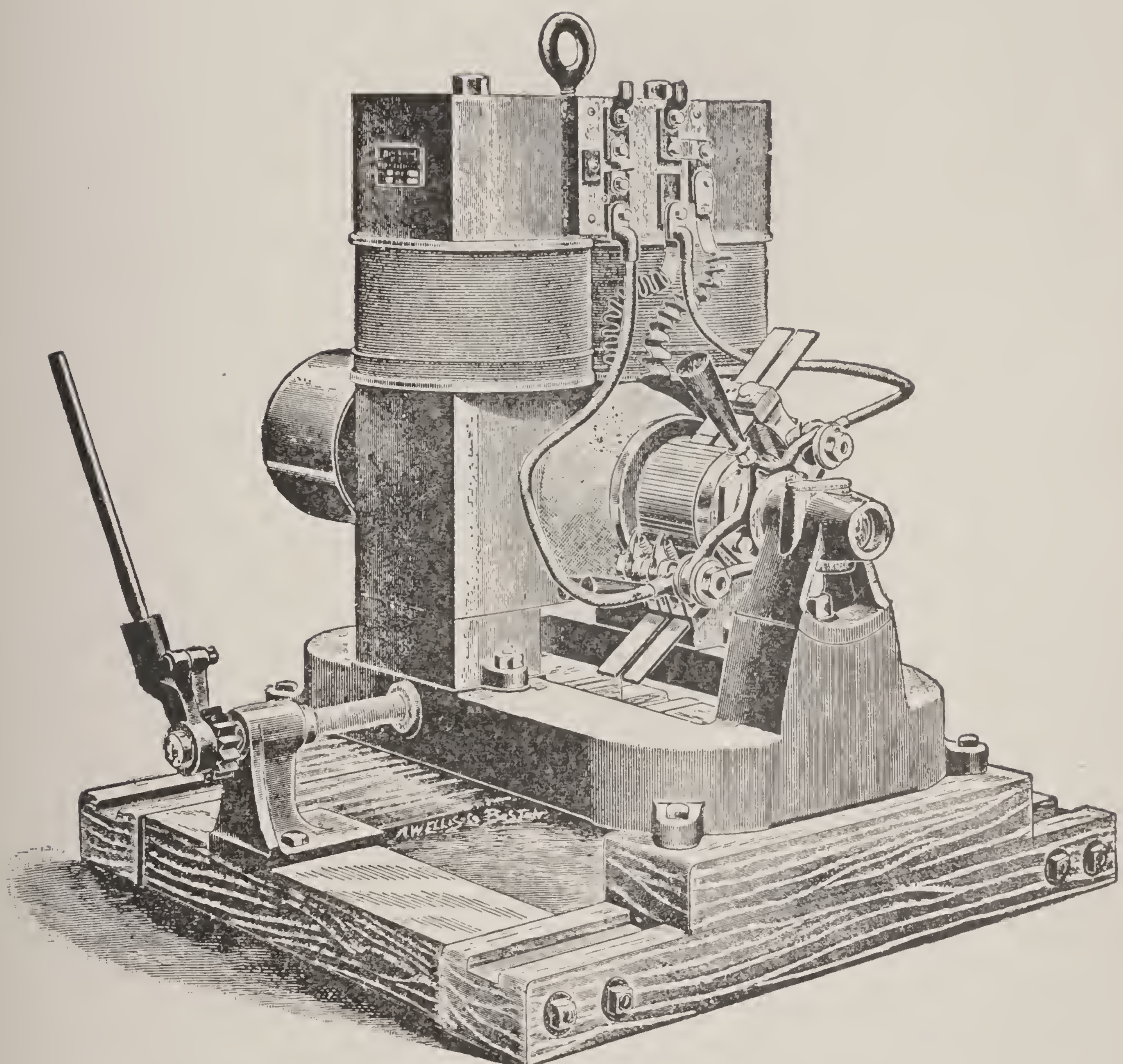
arm and brush holders. The center of gravity of the armature is low, due to the bearings being located to the base frame, great stability is secured. Self-oiling bearings and carbon brushes help to reduce to a minimum the attention necessary to the operation of a dynamo.

The General Electric Company's 800-K. W. Direct Connected Generator. — The careful attention given the design of the large number of railway generators built by the General Electric Company during the past few years has resulted in constant improvements which have brought this type of machine well toward the limit of attainable perfection. The outcome of this constant development is a line of machines which operate sparklessly over a remarkable range of loads, are free from heating and burn-outs under all but the most severe abuse, give no trouble with a minimum of attention, and are practically free from all objectionable features.

The Field Magnet. — The external circular yoke of the field, in all machines of this type, is made of cast iron, and has an oval cross section, except in very large machines, where it is cast with a box-like cross section to give greater stiffness. The upper half of the field is fastened to the lower half by bolts entirely hidden within recesses cored in the side supports, thus doing away with side flanges and improving the appearance of the machine.

The poles are solid steel castings with their outer ends machined to fit accurately the planed faces projecting inwardly from the magnet frame. The use of circular poles of a solid material of high permeability minimizes the length of turns of the field winding, and reduces the waste in this part of the machine.

Armature. — Each arm of the armature spider is cast with its



COMMERCIAL DYNAMO AND MOTOR.

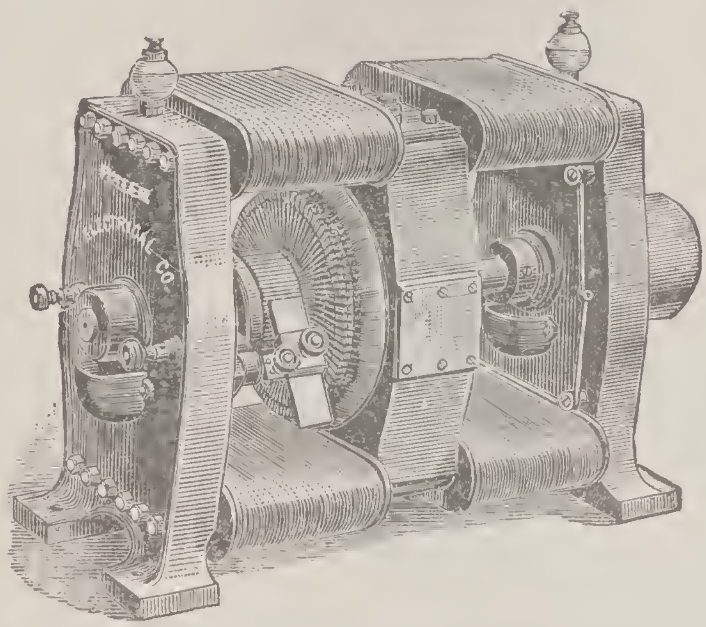
own section of the spider rim, and the rim sections are unconnected except through the hub, until the laminations are dovetailed to them; thus shrinkage strains in the castings are avoided. The arms have wings or fan blades cast to them, which are inclosed by deep extensions of the end flanges toward the shaft. These wings with the radial space blocks in the ventilating passages between the laminations, serve as a forcible centrifugal fan to keep a constant blast of air passing between the laminations and windings and around the poles, thus keeping all parts well ventilated and cool.

The coils are of the usual form-wound copper strip type, held in the slots by wooden retaining wedges, which are sufficient for all ordinary strains, and also by binding bands over the ends, which gives added strength for emergencies such as a runaway of the prime mover. These binding bands are sectional and are fastened with a key, by means of which they may be readily removed or replaced. There are no binding bands on the armature surface under the poles.

Dynamos for Electro-Plating.— Dynamos for electro-plating differ from those in general use for electric lighting in a number of important particulars. The machines used for lighting purposes are wound so as to generate a current of high E. M. F., while a plating dynamo is constructed to give a current of large volume but of low E. M. F. The reasons are that a lighting circuit has a high resistance, while the resistance in a plating circuit is always low. A high E. M. F. is not desired in electro-plating, and this is overcome by using large wire in winding the dynamo, and running it at a low speed. The wires of the external circuit should be large too, so as to carry the current safely.

Among the many good dynamos which are well adapted for electro-plating are the following:

The Wood Dynamo. The engraving gives a very good idea of the size and general appearance of the new improved machine. It is of the Gramme type. In the armature of this machine we have a Gramme ring armature. The core is usually laminated, that is, it is made up of soft iron discs, insulated from each other by thin sheets of paper. These are mounted on a shaft. The insulated copper wire is wound in sections around the external and internal periphery of the ring. The beginning

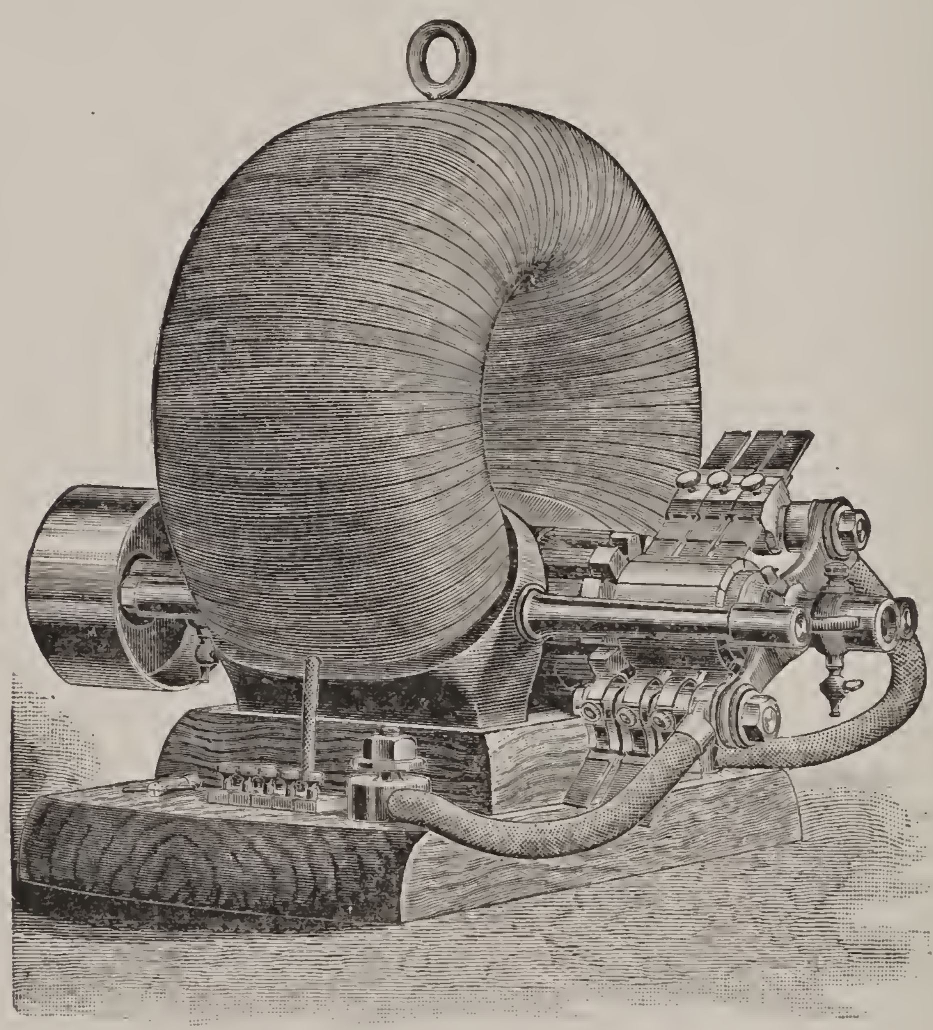


WOOD ELECTRO-PLATING DYNAMO.

and ending wire of each section is left long, and when the ring is wound, the end of one section is twisted up with and soldered to the beginning of the next, and so on all around the ring. Then each twisted end is soldered to a separate bar of the commutator, of which there must be as many as there are sections in the coil. Four field magnets' cores are used, so as to form the four corner yokes between two upright square castings, which form the frame work of the machine. The two upper cores are connected to one pole-piece, and the two lower

to another. The field magnet coils are so wound as to produce a north pole in the piece above, and a south pole in the piece below. The current is continuous, and well adapted to electro-plating.

The Eddy Dynamo electric machines for electro-plating and electro-typing have always enjoyed an excellent reputation. They



EDDY ELECTRO-PLATING DYNAMO.

have been modified and improved from time to time; the latest ones rank high for efficiency, simplicity and workmanship. In this machine the ring form of magnet (Mather patents) and Sieman's armature is used. The field is always charged when the machine is running, so deposition begins as soon as the connec-

tion is made. Owing to the method of winding, it is impossible for them to reverse.

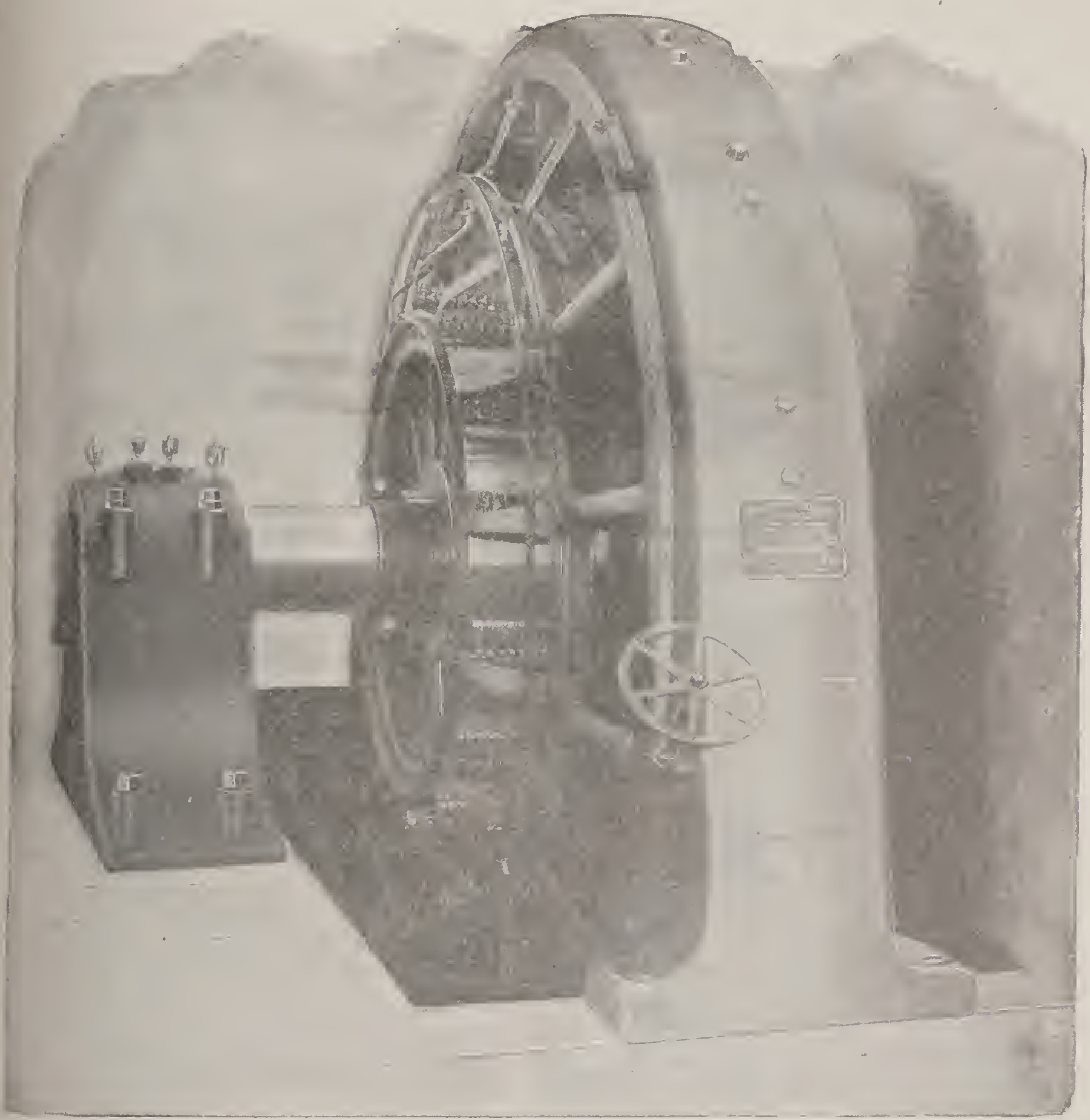
Plug switches are placed on the bases of Numbers 1 and 2, and the principle on which they work is to lessen the resistance of the field, and so keep it from cutting out when heavily loaded. In using the switch, both plugs should be in the outside holes when running on a small amount of work, and as the work increases to the point where the deposition is slow, one plug should be put in the slotted hole marked No. 1, and as the surface in the tanks is again increased, the other plug should be put in the hole No. 2. The No. 3 machine is controlled by switch as above, or by a separate exciter in special cases, and is under perfect control whether it is doing a small or large amount of work.

The shafts are of tool steel, and are ground on dead centers, which insures uniformity. The bearings are of very hard composition, and are self-oiling; they contain flat rings which run on the shaft and carry oil from the reservoir below. The pet-cock under the bearing should be opened every morning and the old oil allowed to run out, then closed and refilled from the oil cups until it fills in the yoke at the end of the shaft. this should last all day. The bearings must not be allowed to run dry. Use a thin pliable belt, the full width of the pulley, and not have it drawn tightly. The pulleys are large enough to do the proper amount of work without being tight against the belt. A stiff, heavy belt would have to be drawn tightly, and would, in consequence, wear out the bearing sleeves.

The commutator segments are solid, and extend down to the shaft, and with proper care will last a very long time. The brushes should be set so that the point of contact on the com-

mutator of the top and bottom brushes shall be diametrically opposite. Adjust the brushes to insure a light but sure contact. Do not set them hard enough to cut the commutator. File the ends to a bevel that will bear flat on the commutator and keep t em so. Do not have the bevel at such an angle that only the front edge of the brush, or perhaps the corner, bears on the commutator. Such a condition of the brushes is liable to produce sparking. If they are properly trimmed and set, the machine will run without sparks. Do not let the brushes and commutator get gummed up with oil. All the working current passes through the brushes and a good contact between brushes and commutator is indispensible. Keep the commutator clean. Do not deluge it with oil. Shift the brushes occasionally to a different place on the commutator, so as to wear all parts alike, and not cut channels or grooves in it. In setting the brushes, make allowance for the end shake of the shaft, and set them far enough from the end of the commutator so that there will be no possibility of contact between either brush and the commutator head. For lubricating the commutator, we recommend having a piece of felt which has been soaked in lard oil, and then had plumbago worked into it, which, if occasionally rubbed over the surface will keep it in good condition. A good oil for bearings is a 28-degree mineral oil. Under no circumstances use an animal or a vegetable oil.

The armature is supported in the magnet field by yokes supported by rods connected to the magnet, so rendering it impossible for it to get out of line.



800–K.W. DIRECT CONNECTED GENERATOR.

THE GENERAL ELECTRIC COMPANY'S 800–K.W. MP. DIRECT CONNECTED RAILWAY GENERATOR is shown on page 249.

The Field Magnet. The external circular yoke of the field, in all machines of this type, is made of cast iron, and has an oval cross section, except in very large machines, where it is cast with a box-like cross section to give greater stiffness. The upper half of the field is fastened to the lower half by bolts entirely hidden within recesses cored in the side supports, thus doing away with side flanges, and improving the appearance of the machine.

The poles are solid steel castings with their outer ends machined to fit accurately the planed faces projecting inwardly from the magnet frame. The use of circular poles of a solid material of high permeability minimizes the length of turns of the field winding, and reduces the waste in this part of the machine.

Armature. Each arm of the armature spider is cast with its own section of the spider rim, and the rim sections are unconnected except through the hub, until the laminations are dovetailed to them; thus shrinkage strains in the castings are avoided. The arms have wings or fan blades cast to them, which are enclosed by deep extensions of the end flanges toward the shaft. These wings with the radial space blocks in the ventilating passages between the laminations, serve as a forcible centrifugal fan to keep a constant blast of air passing between the laminations and windings, and around the poles, thus keeping all parts well ventilated and cool.

The coils are of the usual form-wound copper strip type, held in the slots by wooden retaining wedges, which are sufficient for all ordinary strains, and also by binding bands over the ends, which gives added strength for emergencies such as a runaway of the prime mover. These binding bands are sectional and are fastened with a key, by means of which they may be readily removed or replaced. There are no binding bands on the binding bands on the armature surface under the poles.

CHAPTER XV.

TYPES OF COMMERCIAL DYNAMOS.

(ALTERNATING CURRENT.)

THE high potential alternating current system was introduced into the United States in 1885. Since that time it has been continuously developed and improved. On the following pages will be found descriptions of the various machines manufactured by the most prominent manufacturers of the present day.

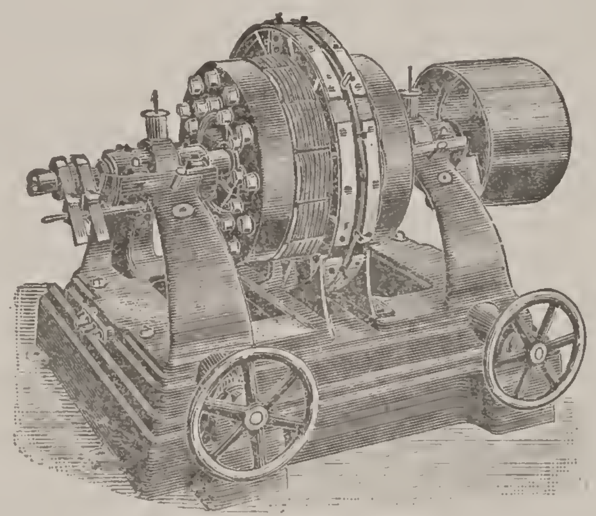
The Brush Alternating Current Dynamo. The underlying principle of the remarkable "coreless" dynamo here illustrated was discovered and applied by Mr. Brush.

The first glance at the dynamo shows that it is novel, compact symmetrical and strong. A brief examination shows that it is of the alternating type; that its field magnets are many and carried by the shaft; that the armature is fixed and absolutely free from any magnetic material; that its parts are easily accessible, and that an armature coil may be cut out, removed or replaced without stopping the machine.

The machine chosen for illustration and description has an output of 60,000 watts; it supplies current for a thousand 16-candle power lamps.

The shaft bearings, bearing standards, base plate and armature slides are cast in one solid piece. The center line of the shaft is $16\frac{11}{16}$ inches above the surface of the base plate, high

enough for access to all parts of the dynamo ana low enough for steadiness and freedom from strain on foundations. The 4-inch steel shaft (tapering to $3\frac{1}{2}$ inches in the bearings) carries two heavy cast iron yoke pieces, 27 inches in diameter. To each of these are screwed, at equal radial and circumferential distances, the wrought iron cores of twelve magnets of alternating polarity. The two yoke pieces, with their bolts, washers, etc., weigh about 950 pounds; the magnet cores, 308; the magnet wire, 400. Thus the whole rotating mass of cast iron, wrought



THE BRUSH ALTERNATING CURRENT DYNAMO.

iron and copper, acts as a fly wheel weighing more than 1,700 pounds, and tending to neutralize any variation in the speed of the prime generator. As the nominal speed of the machine is fewer than 1,100 revolutions per minute, the structural strength is more than sufficient to meet all demands made by centrifugal force. Further than this, the mechanical stress is less when the magnets are excited than when the alternator is running without load, as the lines of magnetic force between the faces of opposing poles, tend to counteract the centrifugal force.

But the most interesting part of the alternator is the fixed armature, shown in the engraving (Figure 157). The vertical disc

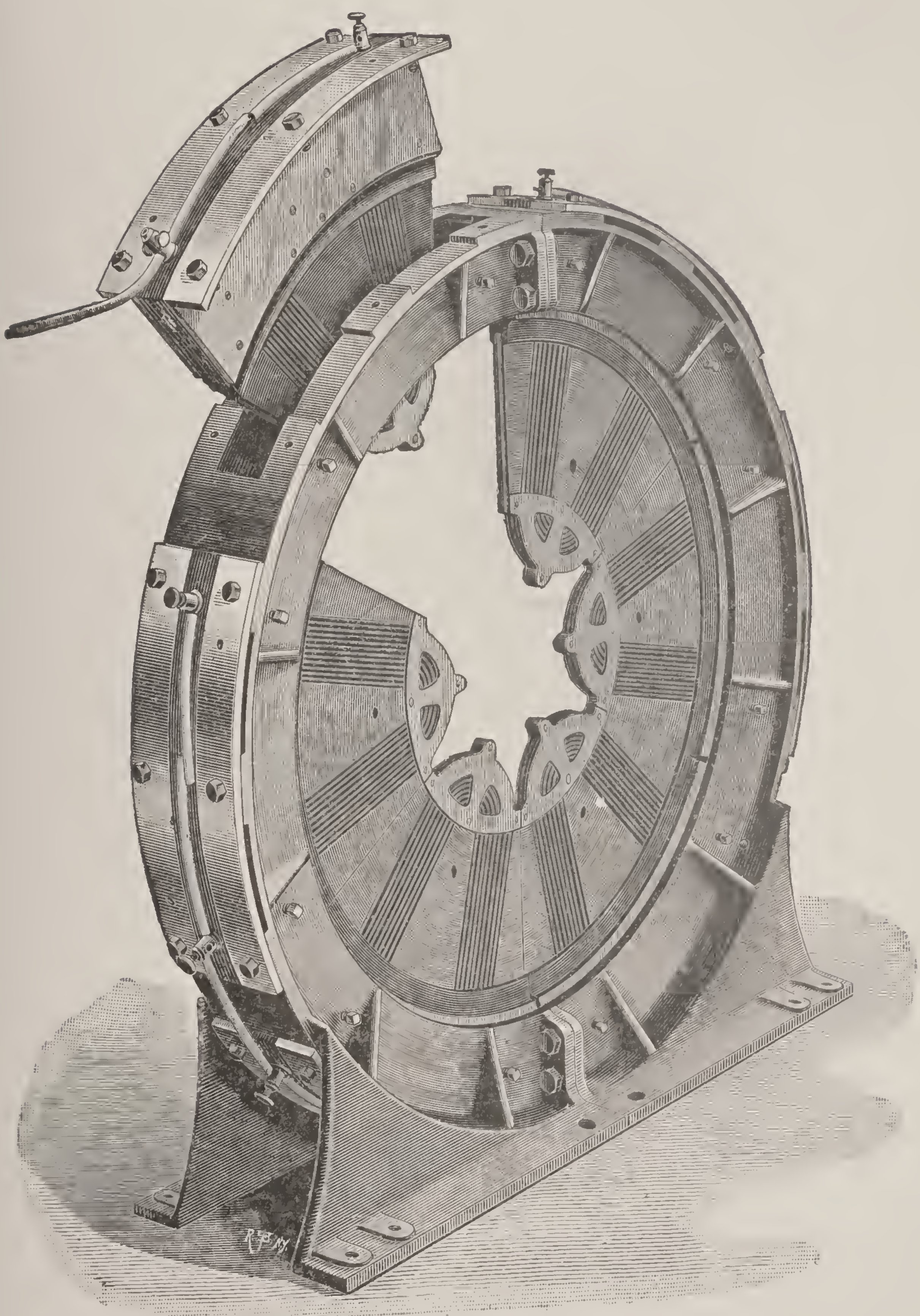


FIGURE 157.

is occupied by flat armature coils, made of insulated copper ribbon wound on porcelain cores. The copper ribbon of each coil is reinforced on either side with strong insulating material of the same thickness as the porcelain. One of these reinforcements is grooved and the other tongued. The coil consisting thus of core, ribbon and reinforcements, has an angular width of 60 degrees. the upper part of each face of each coil, is covered with an insulating plate $\frac{6}{16}$ of an inch thick. The coil thus built up and insulated is set in German silver holders, cut from true turned rings and held together by sunk headed screws, as shown in the engraving. Each terminal of the copper ribbon connects with a binding post as shown.

The six armature coils thus mounted are carried in a German silver frame consisting of two semi-circles bolted together on the line of the vertical diameter. The cross section of this ring frame is girder-like. Into the slots of the frame slip the six mounted armature coils the tongue on the edge of the one engaging with the groove on the edge of the next. The coils thus thrust into the intense magnetic field constitute a disc, $\frac{9}{16}$ of an inch in thickness, and with an opening in the center through which passes the revolving shaft. As there is no magnetic metal in the armature there are no local currents to waste the energy.

The several coils are insulated carefully, and the stationary armature, as a whole, is is insulated from the bed plate on which it rests. The coils are joined in series, the binding posts adjacent to any radial line of division between the two coils constituting fixed terminals for the main line. There is no commutator; there are no collecting brushes to take the alternating current from rotating parts.

The low resistance of the armature coils is evident. It would seem impossible for one of them to burn out; none ever have burned out. But if one should, it may be removed and a new one readily put in its place in three minutes, or the injured coil may be shunted out of the circuit and the dynamo kept running with the other five until the time for shutting down. The coil section complete weighs only about 20 pounds.

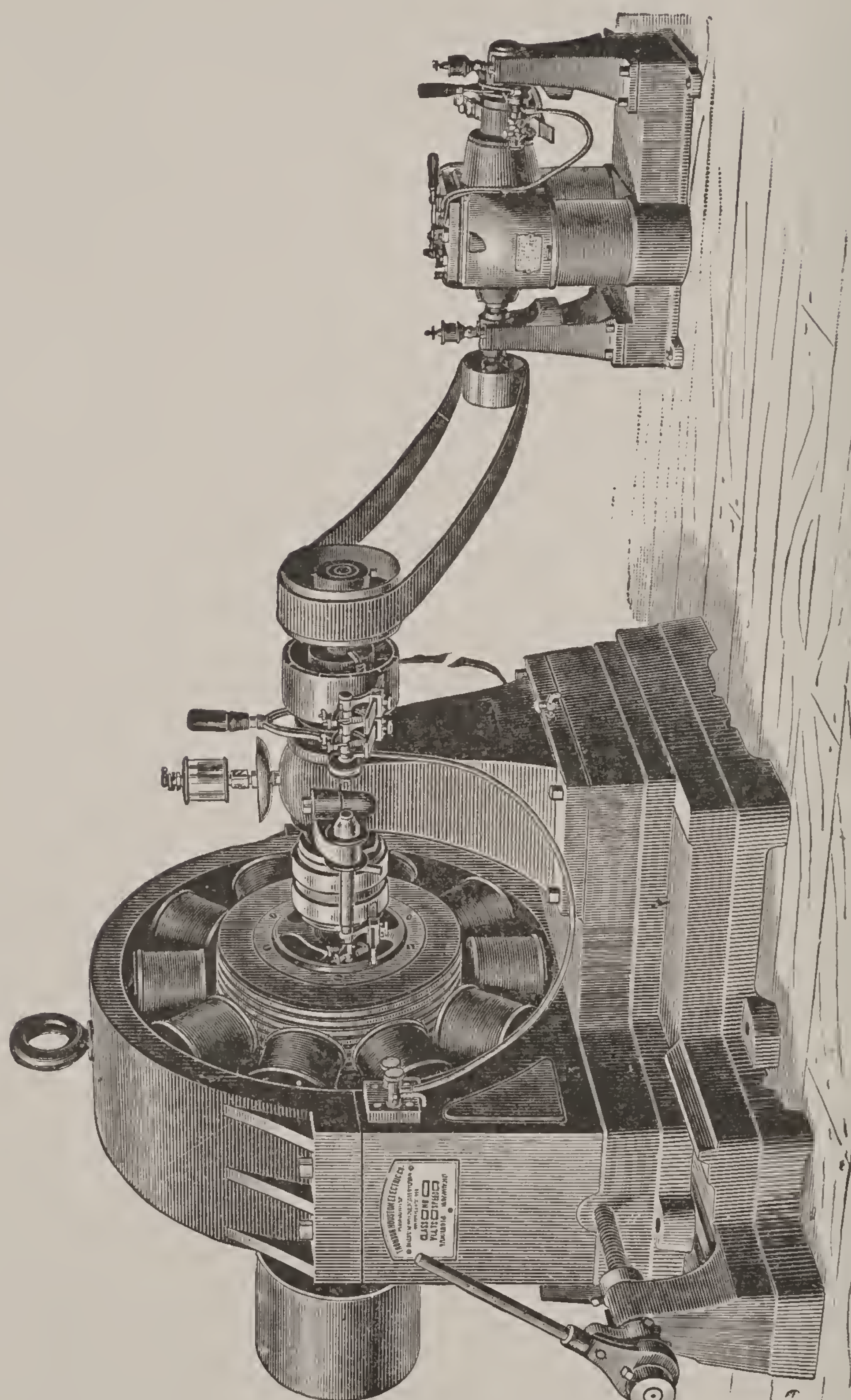
In action, the 24-field magnets of the alternator are excited by the direct current from an 11-inch Brush dynamo of the well known form. This exciting current is carried to the brushes that rest upon the two uncut insulating rings, and thence through the hollow shaft to the magnets. A rheostat worked by hand or automatically is placed in the shunt circuit around the field magnets of the exciter, so that perfect regulation is secured without readjustment of the brushes or any necessity of handling the high-tension alternating current.

The Brush Pfannkuche "coreless" alternator is built at present for an E. M. F. of 2000 volts.

The Thomson-Houston Alternating Current Dynamo shown in the illustration differs very materially from the well known types of machines made by this company, but has the same characteristics of excellence and embodies new and original ideas in dynamo design.

The Thomson-Houston company recognizing the advantages of automatic regulation have produced a machine that, differing from any other on the market, is self regulating for all changes of load, keeping the lights at a constant brilliancy. This is accomplished by an arrangement of the coils on the field magnets of a dynamo, called a "composite field."

A part of the magnetic field is maintained by means of cur-



THOMSON-HOUSTON ALTERNATING CURRENT DYNAMO.

rent from a separate or exciting dynamo. If the load upon the outside circuit is increased, it is necessary to increase the magnetism of the field in order that the machine may in turn supply the increased demand in the circuit and the lights remain steady.

This is accomplished in other machines by varying the current on the field magnets by a rheostat or variable resistance by hand. In the Thomson-Houston Dynamo, however, the same result is obtained entirely automatically by passing the greater portion of the main current through two or more field magnets, thus energizing the machine in exact accordance with the demands made upon it. As an alternating current is not suitable for magnetizing the fields, it is necessary to change the character of the current before passing it through the special winding on the field; and this is done by a commutator at the end of the shaft. By this regulation the attention required at the dynamo is reduced to a minimum, while at the same time the efficiency of the machine is increased, and any number of lamps from one to the full capacity may be thrown on or off without in any way affecting the steadiness and brilliancy of those remaining.

To allow for a pre-determined percentage of loss in the wiring, it is necessary as the load is increased, that there should be a definite amount of increase in potential, which is accomplished by placing around the field winding for the main current a resistance which shunts that portion of current not required for regulation.

The coils for field magnets are wound on spools which are slipped over the castings and fastened firmly in position. These being well protected, the liability of mechanical injury is reduced

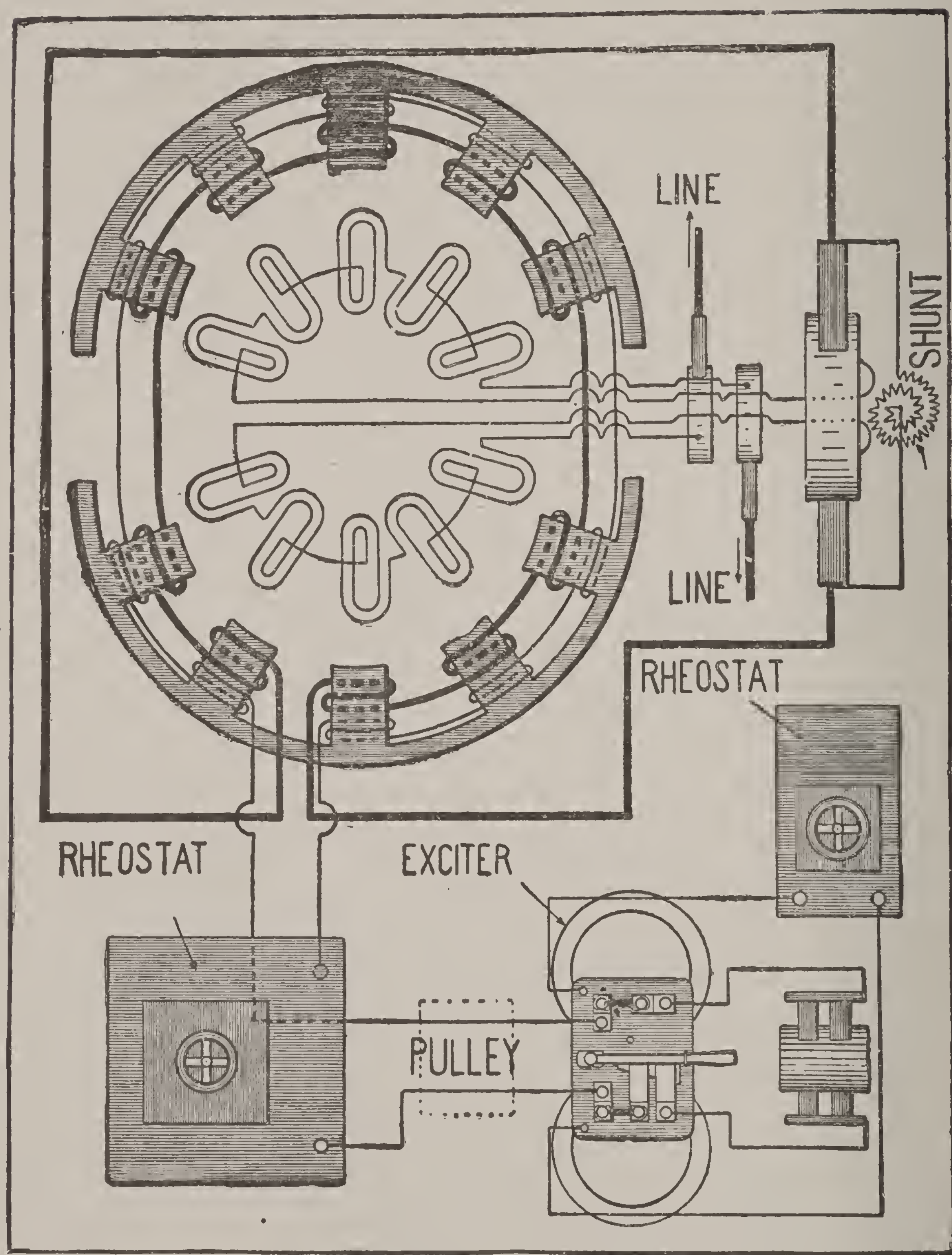


FIGURE 158.

to a minimum. In case it is necessary to replace a coil or to remove the armature, the upper half of the field casting can be readily removed, leaving the parts easily accessible.

The potential of the alternating current requires that the utmost care be used in design and construction of the armature. It is wound with one layer of wire, ample provision being made for insulation between the wire and the iron core, as well as between the separate coils of which this layer is composed. These coils are carefully covered by a material possessing high insulating and protective qualities, and the whole is held in place by bands very firmly wound and fastened. The form of the core is such that perfect ventilation is secured, thereby entirely obviating any tendency to overheating.

The collectors consist of two copper rings from which the current is conducted by means of narrow brushes, which require no adjustment, beyond that of the tension springs governing the pressure of the brush on the collector ring.

The dynamo is supplied with a cast iron base, or bed plate which is provided with a rachet belt tightener.

For the purpose of energizing the field magnets, the dynamos are furnished with small exciting dynamos of the direct current type. It has been found desirable in some special cases to make the smaller sizes of the alternating current dynamos self exciting, and to this end the armatures are wound with an extra or special coil for furnishing current to energize the fields.

The exciter is usually placed as shown in the cut, behind the alternating dynamo, driven by a belt from a small pulley attached to the armature shaft. One exciter is usually employed with each alternating current dynamo, but when several dynamos are operated in the same station it is often found more conven-

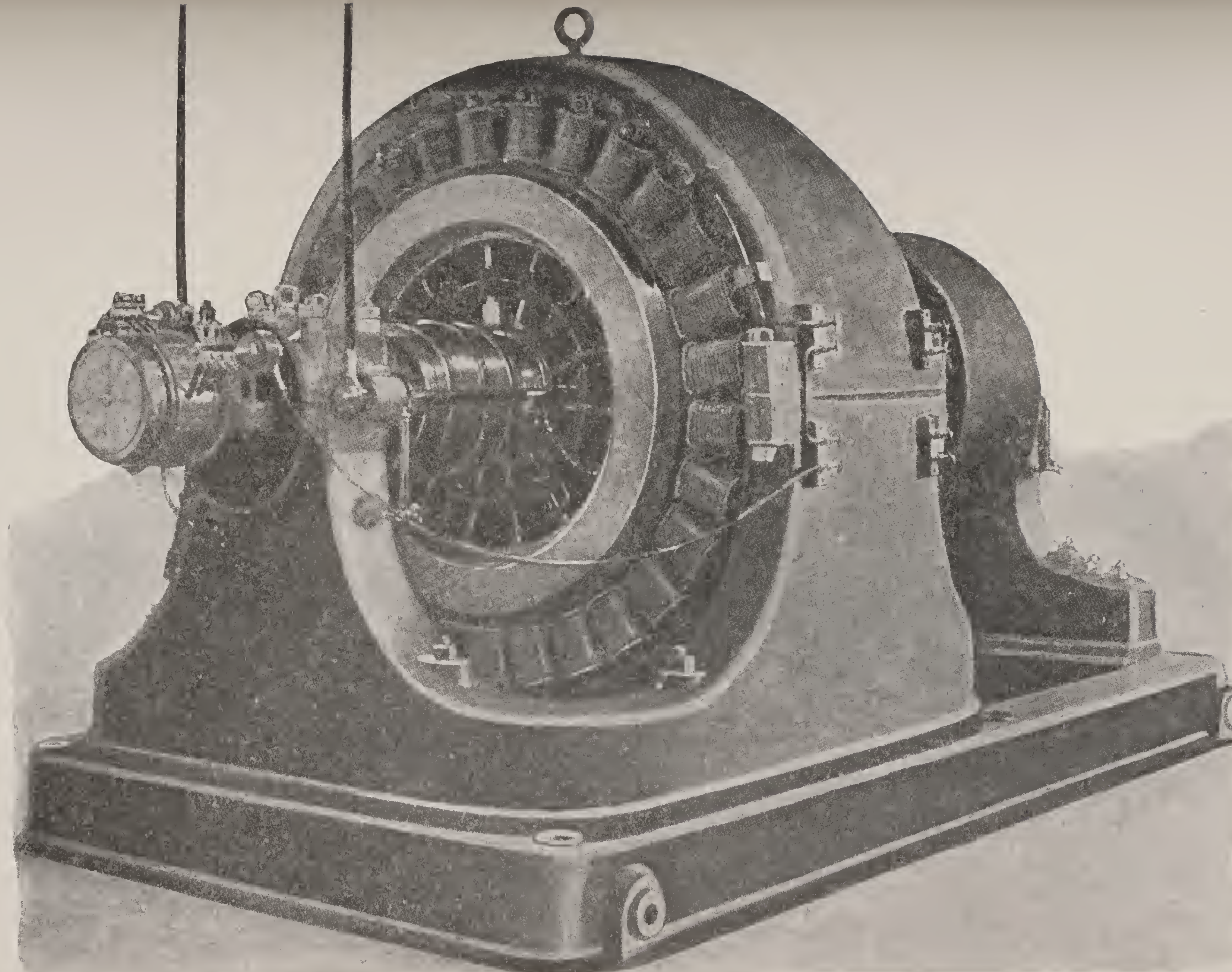
ient to employ exciters, any one of which is of sufficient capacity for all the machines. By this arrangement an accident to one exciter need not affect the general service.

As previously stated, when lights are required to be supplied at different degrees of voltage or pressure it is necessary to use what is called a transformer, which is made on the principle of the induction coil, having two coils, a primary and secondary, and is operated by induction. By induction we mean "A current is said to be induced in a conductor when it is caused by the conductor cutting lines of magnetic force. A fluctuating current in a conductor will tend to induce a fluctuating current in another running parallel to it. A static charge of electricity is induced in neighboring bodies by the presence of an electrified body. A magnet induces magnetism in neighboring bodies."

By sending the current from the dynamo through the smaller or primary wire, the voltage is lowered in the secondary coil with a corresponding increase of quantity, or by sending the current through the larger or secondary coil; the current in the primary coil is raised in voltage but is less in quantity.

The two coils are carefully insulated from each other and from the iron core, thus preventing the high potential current from reaching the secondary or house line. As an additional security in case any such connection is made, there is included in the secondary wiring of each transformer a Thomson automatic protective device, which, in case of contact between the primary and secondary coils, will cut the transformer out of the circuit.

Transformers are made which may be used in connection with lamps of either 52 or 104 volts, it being only necessary to change a connection in the transformer for a change in the



WESTINGHOUSE CONSTANT POTENTIAL ALTERNATING CURRENT GENERATOR.

potential of the secondary circuit. A weather proof iron case contains the transformer, with the necessary safety fuses and connections for the primary and secondary wires. A special arrangement makes it possible to cut the transformer out of circuit while replacing fuses.

The station transformer is used for supplying current for the potential indicator and lamps upon the switchboard.

A diagram of a composite field piece and connections is given in Figure 158.

Westinghouse Constant Potential Alternating Current Dynamo. To the practical central station manager the accompanying illustration of the constant potential alternating current generator will at once commend itself. The main frame of the machine is in two parts, securely bolted together, and which separate on a horizontal plane. The upper piece, or yoke, can be readily lifted off for inspection or repairs without the dynamo base being in any way disturbed. The whole design is rigid, and the pole pieces projecting radially inward are in such a position, and are so proportioned, that there is almost no external field, the entire exciting current being utilized with a minimum waste of energy. Ball bearings give a perfect alignment to the armature shaft, there being a self-oiling chamber to secure perfect lubrication at each bearing.

With the rapid growth of the electric lighting industry, and the establishment of central stations to supply the needs of our large cities, has come a demand for a system of combined incandescent, arc and power service, to meet which has been designed a line of generators operating at the rate of 7,200 alternations per minute, 16,000 alternations having been the exclusive practice in the past. The result accomplished by this reduction in the number of alternations are briefly as follows:

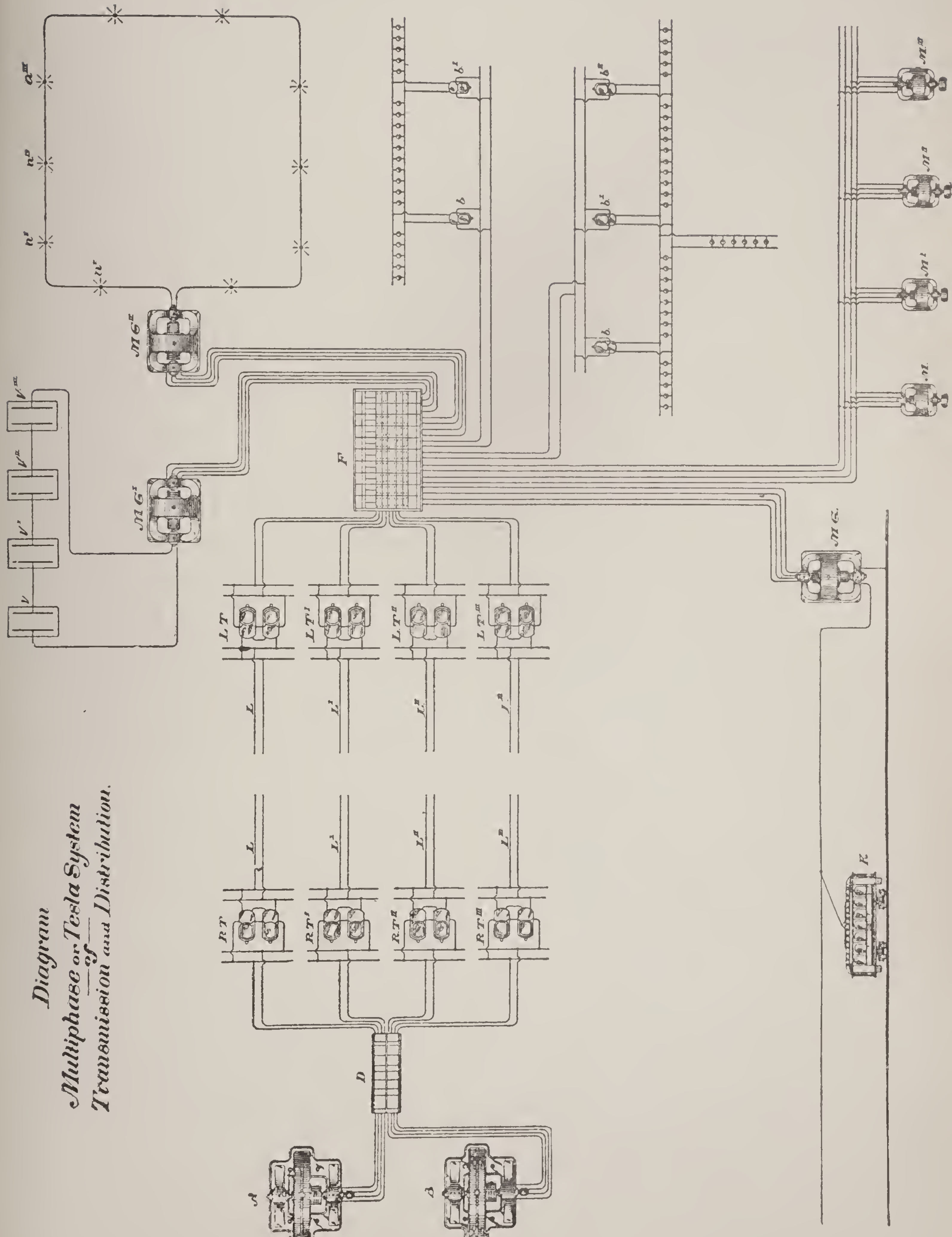


Diagram
Multiphase or Tesla System
of
Transmission and Distribution.
MG
F
D
LT
RT

FIGURE 159.

Following the natural course of improvement in mechanical, as well as in electrical design, has come a demand for slower belt speeds, easy running machinery, and great economy of floor space. At 16,000 alternations per minute the number of pole pieces required, in order to reduce standard speeds, is so great as to make the machines heavy, cumbersome and expensive, especially as the speeds are reduced to an extent which will permit the direct connection of the generator to an engine or turbine shaft. The latter condition is one requisite in order that the minimum floor space may be attained, and such connection is in many cases possible with the 7200 alternation generators.

The Tesla Polyphase System lends itself to every purpose for which electrical power is used. It may fairly be called a universal system. It is equally adapted to supply light or power. It will supply arc lights or incandescent lamps. It furnishes power through motors of the rotary field type or of the polyphase synchronous type.

By means of commutating devices, direct or continuous current is readily obtained for the operation of street railway systems, for electrolytic work, and for all other purposes requiring this kind of current.

By it we may use alternating current for transmission, and may readily obtain either alternating or direct current at practically any potential adapted to any purposes to which electricity is applicable.

The universal application of the system is illustrated in Figure 159, on page 263. The generators A and B, are located at the generating station, and are driven by turbines. Each generator delivers two distinct alternating currents to raising transformers, RT, RT′, RT″, RT‴, through the switchboard D. The cur-

rent, as generated, is of low potential, and may be handled with entire safety, but the raising transformers deliver their currents to the transmission circuits, L, L′, L″, L‴, at a very high potential, e. g., 10,000 volts. At a point conveniently located with reference to the district where lights and motors are to be supplied, a sub-station is erected. The transmission circuits enter the station and deliver their currents to the step-down or reducing transformers, LT, LT′, LT″, LT‴, which, in turn, deliver currents at moderate potentials suitable for local distribution. The switchboard, F, affords means whereby the circuits coming from the various groups of lowering transformers may be readily transferred and interchanged, so that any of the transmission circuits may be used to supply any of the local distributing circuits, as may be advantageous or convenient. In the diagram, beginning at the left of the switchboard, the first four-wire circuit is used to supply alternating current to the motor generator or rotary transformer, MG, which, in turn, delivers direct current at 500 volts to a trolley line, from which the street car, K, is supplied. The second circuit supplies the motors, M, M′, M″, M‴, —of the two-phase synchronous type, or of the rotary field type, —which are adapted to general power purposes in mills, factories, etc. The next four-wire circuit is divided into two two-wire circuits, and is used to supply incandescent lamps through the transformers, b, b′, b″. The next circuit supplies alternating current to the motor generator, MG″, which delivers direct current for arc lighting purposes. The last circuit shown supplies the motor generator, MG′, which, in turn, delivers direct current at low potential for electrolytic purposes, as indicated in the vats, V, V′, V″, V‴. If the frequency employed be sufficiently high, (say 50 periods per second, or 6000 alternations per minute)

constant potential alternating current arc lamps may be supplied from the secondary circuits of transformers.

There are several types of two-phase alternating current generators, among which two are especially prominent. Machines of the first type are really double machines, having two fields and two armatures, — the latter mounted on the same shaft. Each armature delivers alternating current to a two-wire circuit, and these circuits taken together constitute the four-wire circuit of the generator, or they may be so connected as to constitute a three-wire circuit.

Machines of the second type have single armatures with two windings, or with a single winding so connected to the ring collectors as to deliver two currents differing in their time relation or phase. The machines of this type are very similar in appearance to the direct connected generators. In place of the commutators ring collectors are used, but in other respects the construction is not materially modified.

Field Magnets for Dynamos. For the convenience of the reader, an illustration of a number of different styles of field-magnets is given on page 267. In many cases the structure which acts as a magnet has also to do duty as a framework, which involves considerations that may interfere with the magnetic circuit. But the rule is to seek for the circuit of highest permeability. This will consist of the most compact form, greatest cross section, softest iron, and fewest joints.

SOME VARIOUS FORMS OF FIELD MAGNETS (ALTERNATING AND DIRECT CURRENT).

CHAPTER XVI.

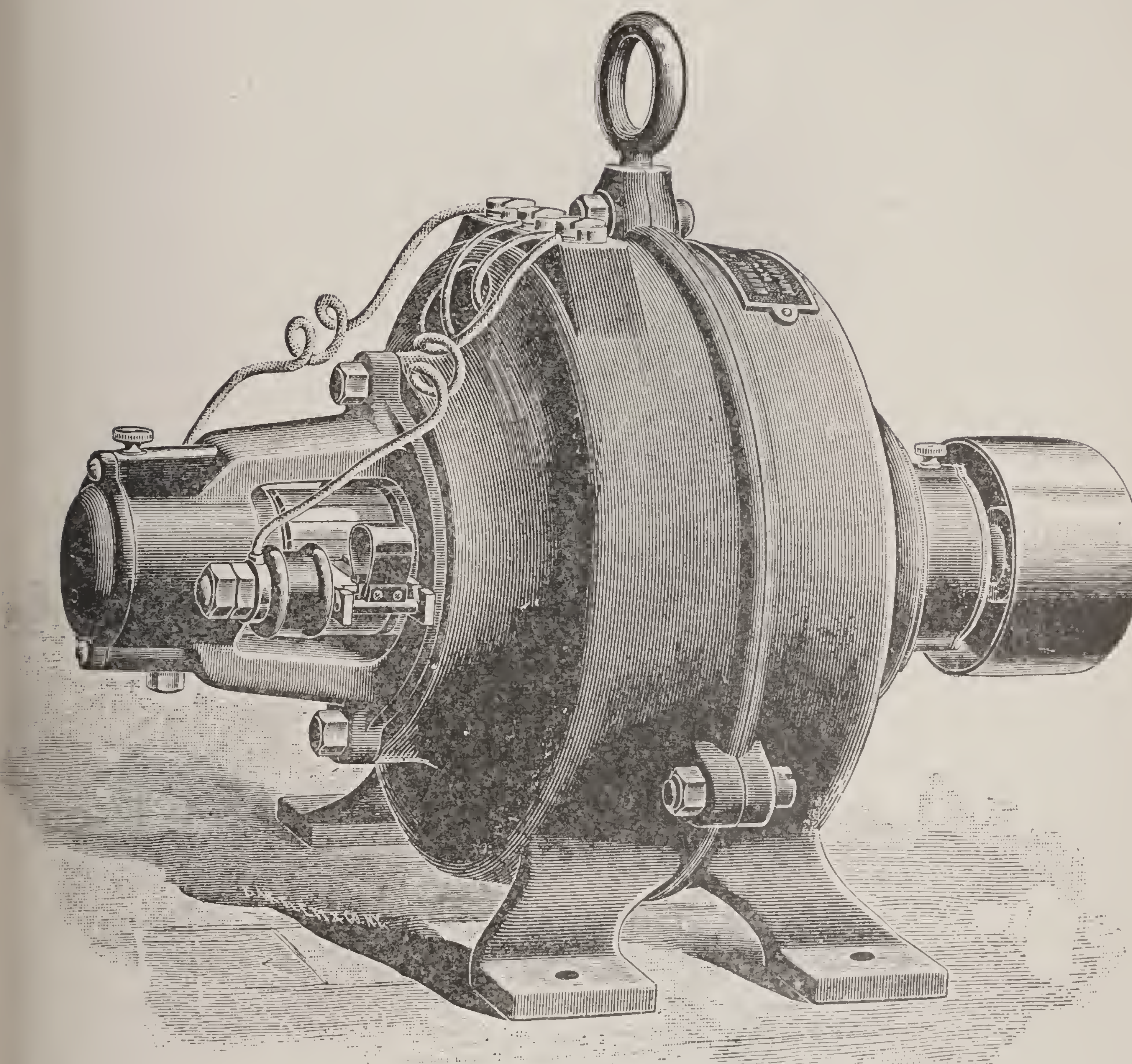
TYPES OF COMMERCIAL STATIONERY MOTORS.

OF the many kinds of stationary motors we select and give the following:

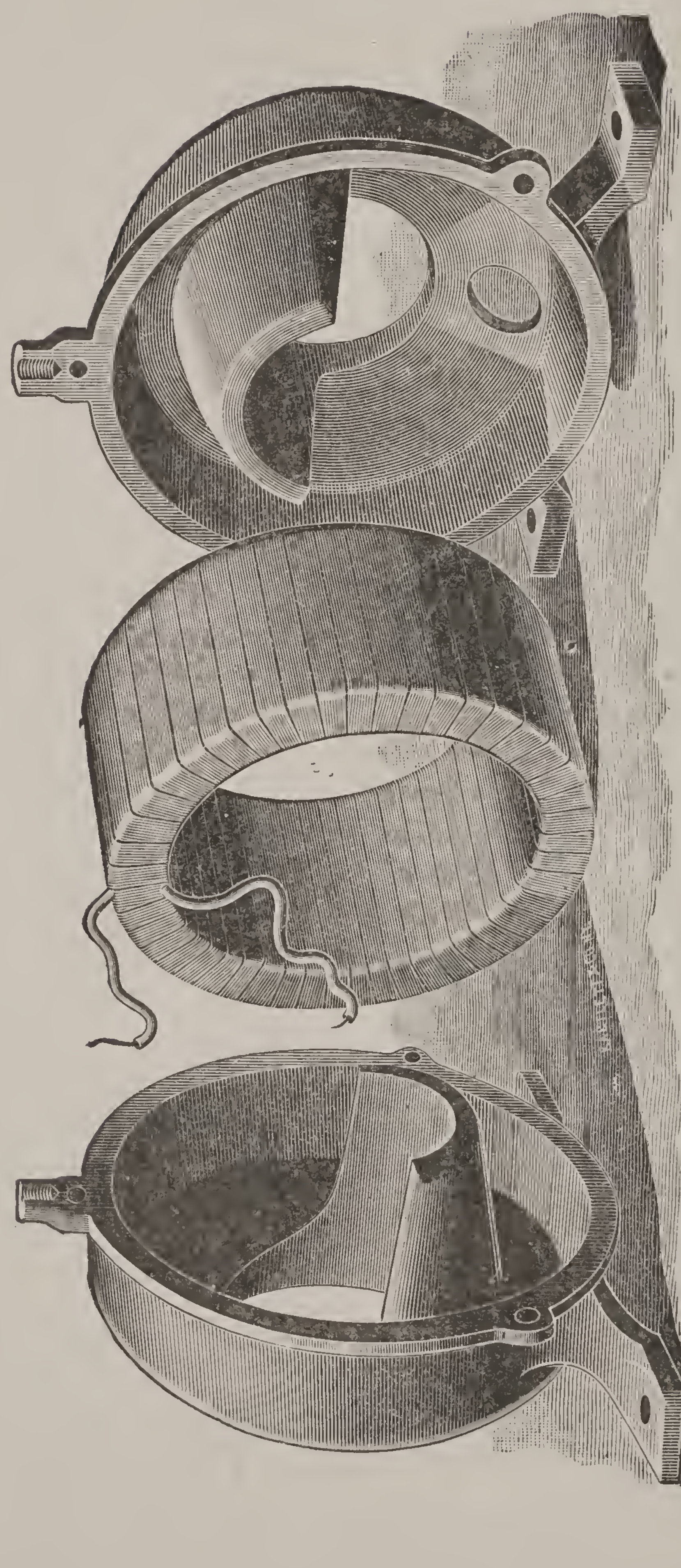
The Lundell Motor. These motors are made in six sizes, ranging in power from $\frac{1}{4}$ of one horse-power to 5 horse-power, being wound for 115, 230, or 500 volt circuits, as desired.

The amperes taken at full load and 115 volts range in the six sizes from 2.2 to 45.

The Interior Conduit Company claims that in some respects these power motors are superior to the fan motors manufactured by them, and that their merit consists in the high development of the factors of high efficiency, simplicity, compactness, light-weight, cleanliness, and neatness of appearance. In these motors the company has been enabled to incorporate some qualities not obtainable in the fan-motor size; as, for instance, by the simple fact of increased dimensions the form becomes cylindrical and this permits the placing of the field coil concentric with the armature instead of at an oblique angle. The concentric position of the field coil permits the withdrawal of the armature without disturbing pole-pieces—a very great advantage in motors of any considerable power. A further modification is obtained in placing the commutator outside of the field magnet shell, but well protected between the two limbs of a broad and strong bracket.



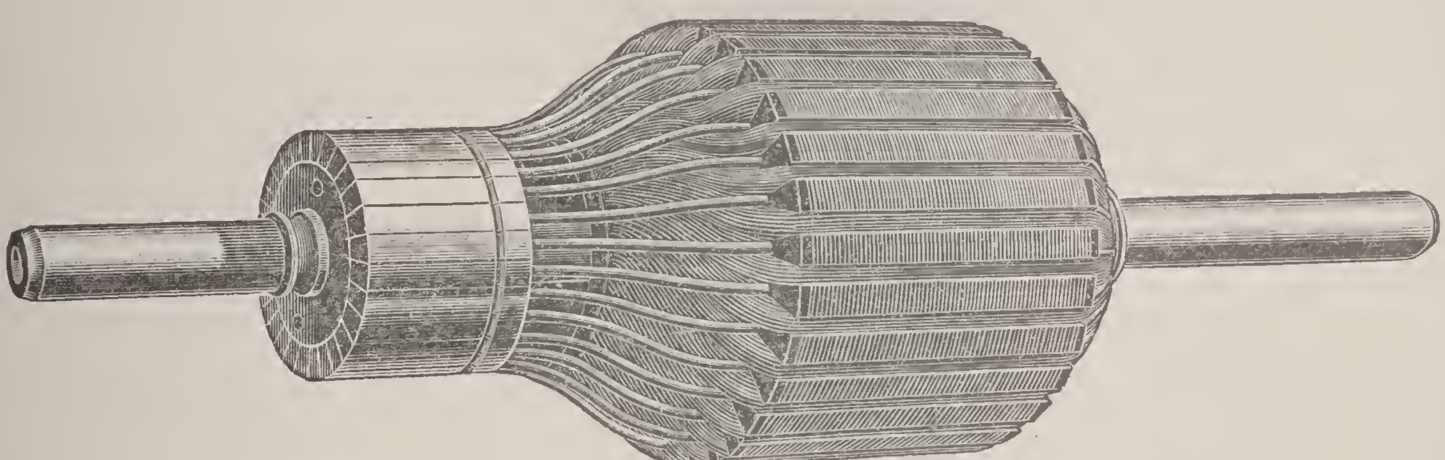
THE LUNDELL MOTOR.



FIELD AND POLE PIECES—LUNDELL MOTOR.

This change of commutator position is made for the purpose of affording the ready access to brushes and commutator demanded by motors employing a current of any considerable quantity.

The brush-holder as well as the commutator are of superior design and workmanship, the former being extremely simple, enabling the renewal and restoration of a brush with great ease and in a second or two of time. The armature is of excellent design and workmanship; it is substantially built and combines maximum cross sections with minimum length of wire. This,



THE ARMATURE—LUNDELL MOTOR.

the company claims, secures high efficiency and low speed variations between extremes of load. This is a shunt-wound motor, in fact, which practically fulfils the duty and office of a differential motor.

In regard to the bearings, the same careful attention has been given as to the other parts. They are self oiling and provided with a vision gauge by means of which the condition of the oil supply can be seen at a glance. The bushings are made of the best material and are easily removed and renewed when worn out.

Each motor is furnished with a Lundell regulating and starting box or a Carpenter enamel rheostat as desired. The advan-

tage of the latter is that it occupies a very small space; it is also fire-proof and water-proof and is mechanically strong and simple in construction.

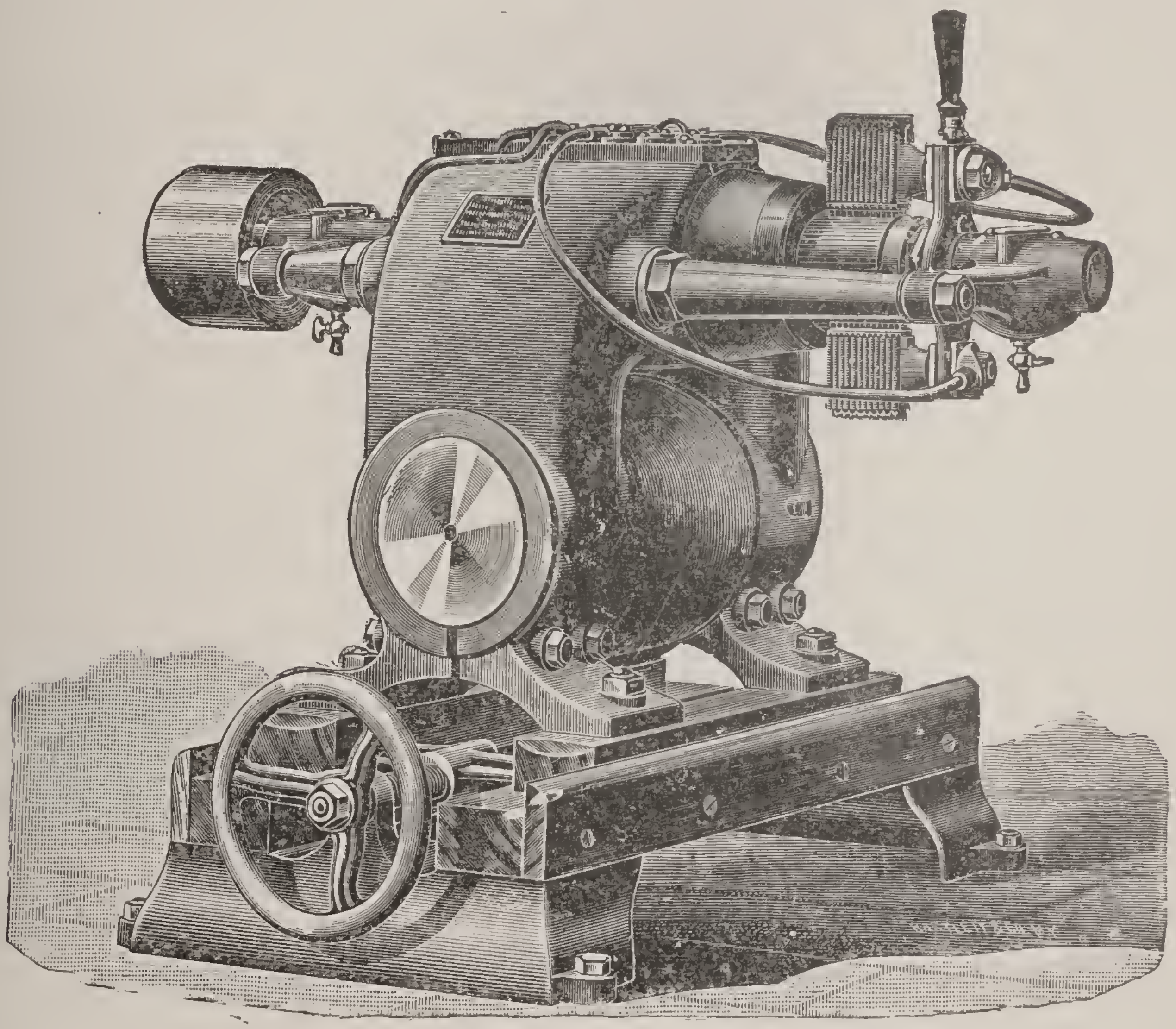
The Jenney Automatic Electric Motor, illustrated on page 273, shows one type of the constant potential motors. This machine is widely different from those in general use, the armature, field-magnet and shape of pole pieces being its characteristic features.

The aim has been to produce a magnetic field of enormous strength, which will, at the same time, be economical to maintain. By studying the direction of the magnetic lines of force about a straight bar magnet, the inventor was led to design the form of magnet shown. The natural direction and curvature of the lines of force, as they pass through the air from one pole to the other in a bar magnet, are well known. In this machine the pole-pieces were made to correspond with the natural curvature of the lines of force, thereby reducing to a minimum the length of the magnetic circuit, and its resistance.

There is but a single field magnet, and in all sizes the core is made of the softest wrought iron. No yokes are needed. The pole-pieces are made of soft cast iron of the best quality for the purpose. There are no projecting ends or corners, with their attendant loss of magnetism. The cores extend entirely through pole-pieces, which are bored to fit them accurately. The pole-pieces are then slotted, and by means of bolts are firmly clamped to the core. By this means the largest possible surface contact is secured, and a most perfect magnetic union, with an extremely small amount of magnetic resistance.

The armature is of the drum type, and is built up of thin discs, all of which are securely fastened to the shaft. The winding is

a modification of the Siemens method, and the armature is so proportioned that it has but little idle wire over the ends. The electrical resistance is very low, and there are but few turns to each section. It is wound with the greatest care, and so insulated that there is little danger of short-circuiting and burning out. The ends of the armature, and the electrical connections,



JENNEY AUTOMATIC ELECTRIC MOTOR.

are thoroughly covered, thereby protecting them from copper dust or dirt of any kind.

The commutator is insulated with mica, and is of ample width of face to secure the best action and reduce the wear to a minimum.

The shaft is of the best grade of machinery steel, of greatest diameter in its central part, accurately turned, and finished in the best manner possible. All armatures of the same class are interchangeable.

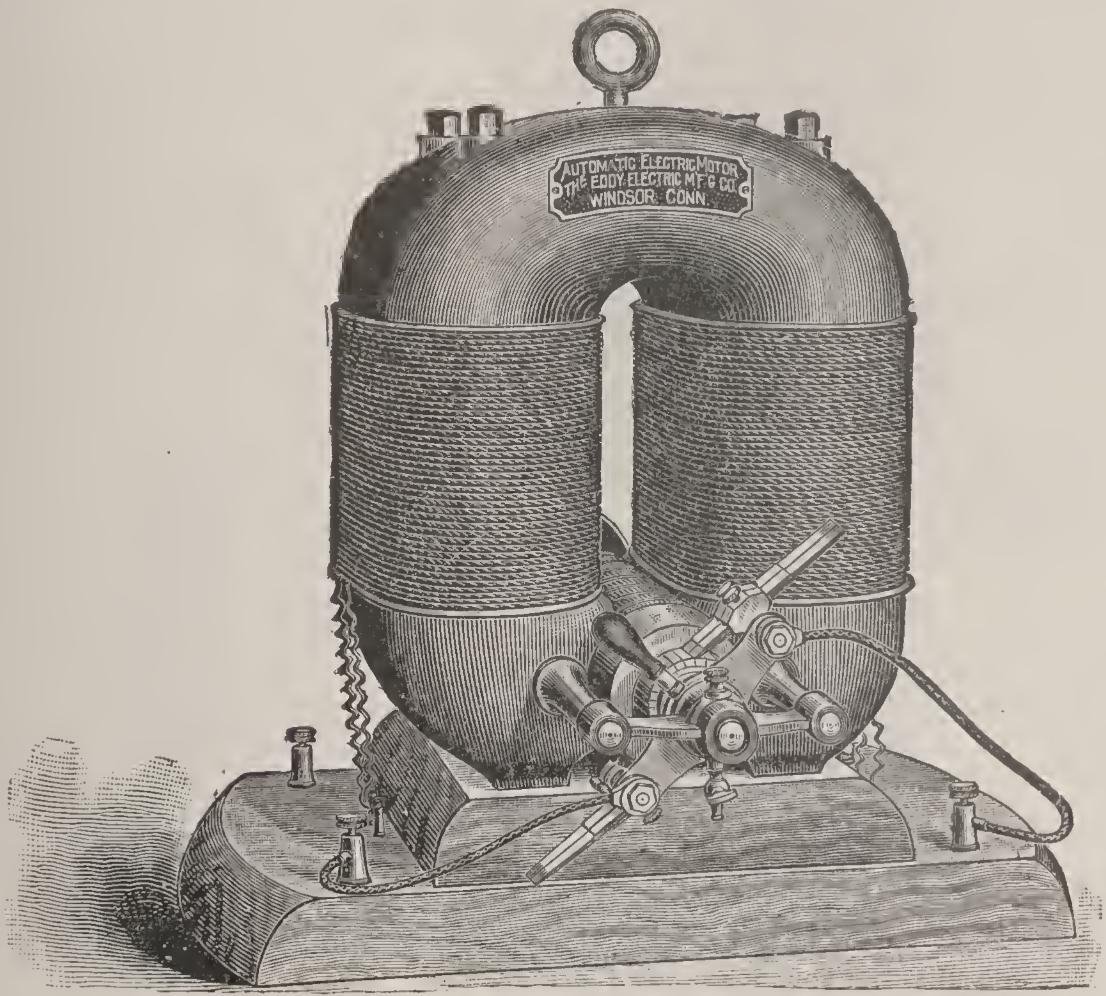
All motors above one horse power are supplied with a double set of brushes, so that the brushes may be turned or changed without stopping the motor. All parts are made after fixed standards and are interchangeable.

The proportioning of the magnetic parts and the windings of the motor is such as to give automatic regulation of speed which is practically perfect, without compound windings of any kind. When the brushes are properly set there is no sparking at the commutator, even under severe changes of load. This removes the necessity for constant attendance, and makes the motor absolutely automatic. The field magnet has a simple shunt winding, so that if a sudden and heavy load is applied, the motor will not reverse its polarity and tend to run backward, as is the case with the compound wound motor.

The Eddy Motor. This motor is designed on the general principles of construction of the Mather type. In this latter form, it will be remembered that the field is a ring; consequently the field coils cannot be wound in a lathe, and the length and numerous turns of fine wire, required for a shunt machine, makes the winding by hand tedious and difficult. It it common to wind a considerable number of wires in multiple, then connect them finally in series to give the requisite resistance; for high potentials this practice is not reliable.

The Eddy Company, while preserving the general excellent ring form of field by use of large round corners have made the coils straight. They can easily be wound in a lathe, using but

one wire and insulating between the layers. Wires having large differences of potential between them do not cross each other. They can safely be wound for all commercial voltages, and attain at a reduced cost, the same high efficiency as the Mather type. The amount of current in the field magnet coils is therefore very

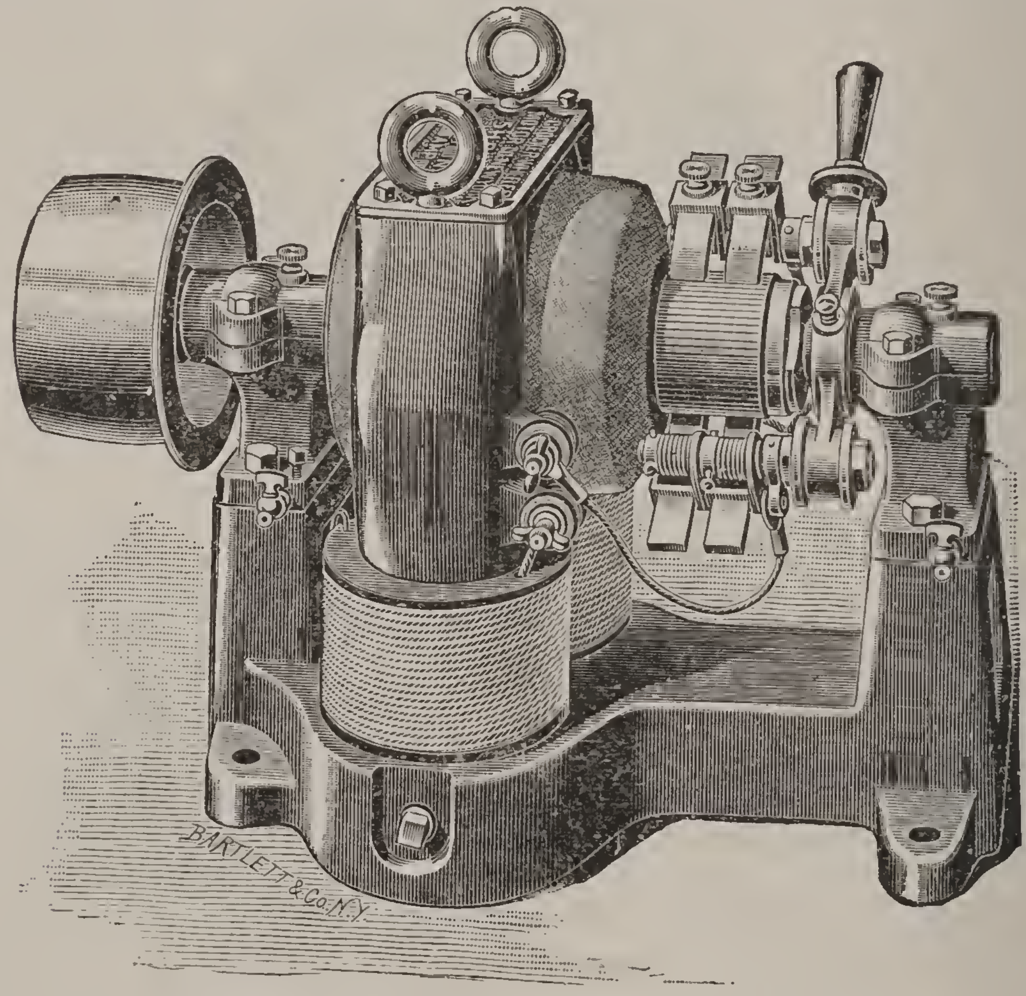


EDDY 15 H.-P. AUTOMATIC ELECTRIC MOTOR.

small. The magnets do not get warm. The watts consumed in charging the magnets of a motor bear no relation to the work done by the armature, and as far as the efficiency of the motor may be concerned may be said to be wasted. It is therefore extremely important to reduce this magnetising current to a minimum in order to produce an efficient motor. At the same time, it will be seen, high efficiency in a motor requires a strong magnetic field.

The Crocker-Wheeler Electric Motor, of which two illustrations are given, possesses some special features of merit which are as follows:

The field magnets are composed of the best wrought iron, each magnet being forged in a single piece, and set deeply into the base in order to secure solidity and ample magnetic contact. The space for wire on these magnets is perfectly cylindrical, in



CROCKER-WHEELER ELECTRIC MOTOR.

the form of an ordinary spool, thereby insuring smooth and perfect winding of the wire, and is short in length, permitting the shaft of the machine to be low enough to free it from vibration. By this construction the neutrality or freedom of the base from magnetism is secured, and there is no tendency to leakage. This is claimed to make the machine much superior to

those in which the base is made to serve as one of the pole pieces, as the bearings then become magnetized and make the shaft bind.

The armatures contain several improvements. They are sufficiently large in diameter to obtain slow speed, and are so designed that the wire winding is entirely embedded below the surface of the iron core, thus protecting it from all injury, holding it rigidly in position, and rendering it possible for the magnets to approach very closely to the core, so that an intense magnetic effect is produced. The armature is fastened upon a brass face-plate, which is first turned perfectly true, and after completion the armature is very carefully balanced, so that when run at full speed the motion is hardly perceptible.

The bearings are all of the self oiling type, which do not require attention oftener than once in two to four weeks.

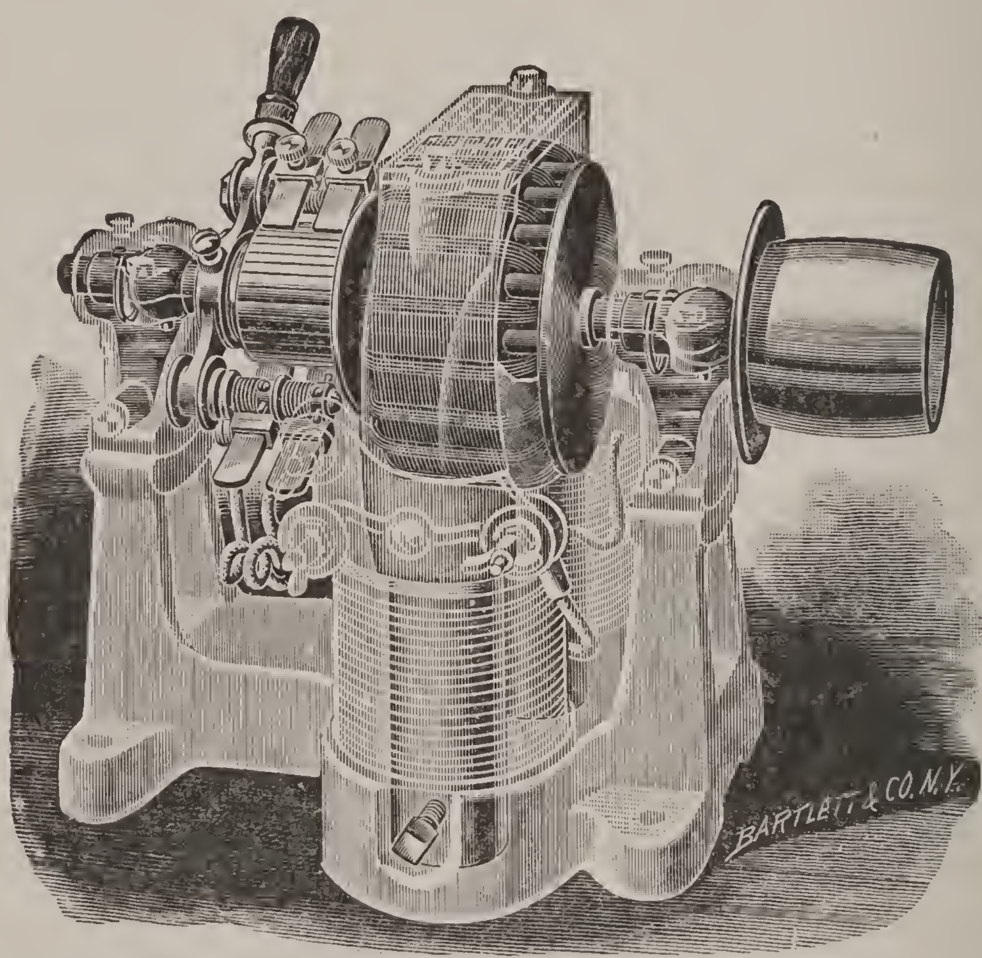
The base of the pillow block is hollow, and contains a supply of oil which is carried over the shaft by two rings which travel upon the latter, and are caused to revolve by its motion. They dip in the oil and carry it continuously to the upper side of the shaft.

The bushings in which the shaft runs rest in turn in universal or ball joints in seats of babbit metal in pillow blocks, so that the bearings are sure to assume perfect alignment when the shaft is introduced. After the motor has run a month, the old oil containing the grit, etc., should be drawn off from the pet-cock at the base of the pillow block. The cock should then be closed and fresh oil introduced by removing the thumbscrew in the pillow block cap on top.

The brushes are held by rocker arms which can revolve freely around the entire circle, without fear of the brass con-

necting parts "grounding" against the frame, a great advantage in special work where motors are to be adapted for use in unusual positions.

With this form of armature core which reaches close to the field magnets, and the high grade of wrought iron used for the latter, it is claimed they are enabled to maintain the magnetism and therefore the power of these motors, with only about one-third as



SKELETON VIEW—SHOWING INTERNAL CONSTRUCTION, CROCKER-WHEELER ELECTRIC MOTOR.

much wire as is used on the fields of the ordinary standard machines. This great saving of wire not only reduces the weight of the machine, but materially increases its efficiency, or the amount of power that can be obtained from a given amount of electricity, for with less wire less electricity is required.

The speed of the motors is very low, which in many cases makes countershafting, etc., unnecessary.

The proximity of the armature core to the field magnets renders a high magnetic pressure unnecessary, therefore the magnetism escaping from the fields is very much reduced.

Double insulated wire is used throughout for the windings, the cores being first wrapped with oiled paper and heavy canvas saturated with shellac.

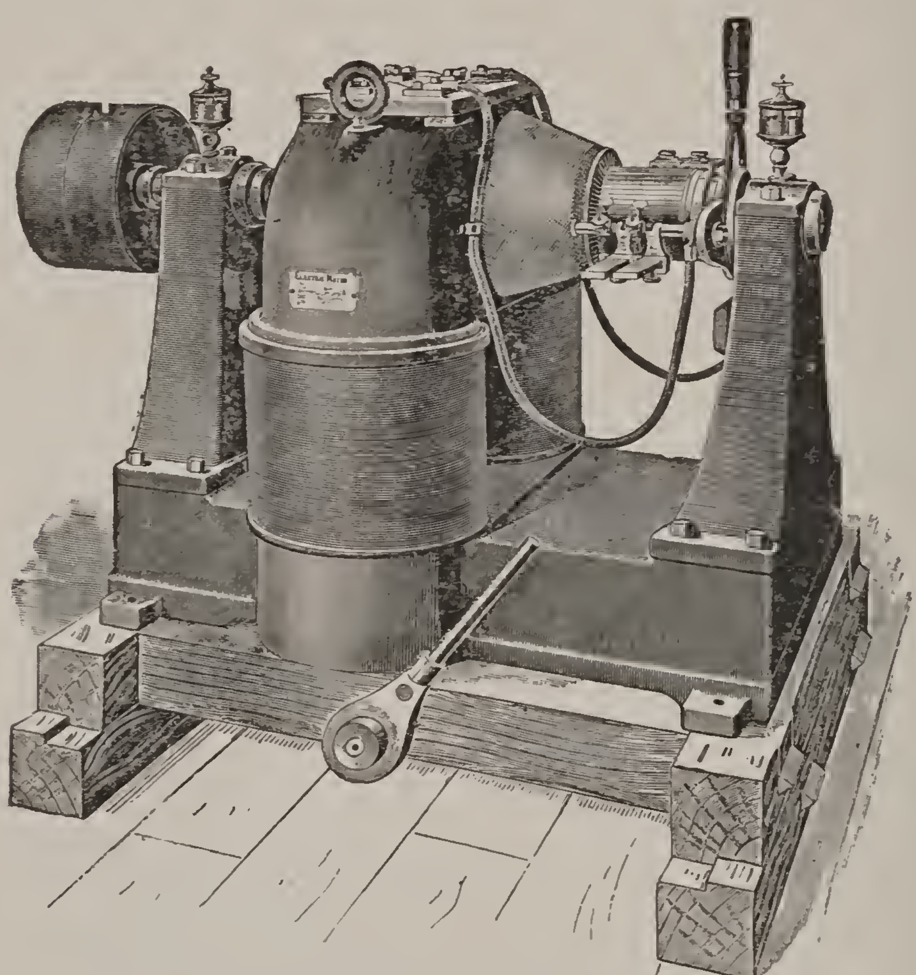
The rocker arm is provided with a heavy insulated handle to enable all adjustments to be made without touching the connecting parts, and the entire machine is heavily japanned and baked at a high temperature, thus securing a polished surface which resists dirt and oil.

In connection with their incandescent motors, they furnish fireproof and indestructible regulating boxes for starting, stopping and varying the speed of the machines. These are built entirely of slate, china and iron. The arrangement of contacts in the switch on top of the regulator is such that both the field and armature of the motor is charged by the single operation of turning the knob, making it impossible to put the current on the armature before the field is charged, which has so often been the cause of the accidental burning out of many motors by the use of ordinary regulators.

The field is first charged through a small resistance coil which is put in for the purpose of preventing a too sudden change in the magnetic strength of the latter, as well as to divide the spark when the motor is disconnected. The coils used for starting the armature are all of the same size wire carefully tried for carrying the full current of the machine at all speeds. With the fireproof regulator, the motor can therefore be slowed

down and left running at any desired speed, indefinitely, and the usual caution "never to leave the box half turned on for fear of overheating and fire," is unnecessary.

The Thomson Houston Stationary Motor. The 15 horse-power motor shown in the illustration has an average commercial efficiency when fully loaded of 91 per cent. This high efficiency



THOMSON-HOUSTON STATIONARY MOTOR.

is obtained by paying careful attention to the electric and magnetic proportioning of the motor.

The magnetic circuit is very short and of ample section, and therefore of low resistance, and the magnetic poles are so formed as to convey the magnetism into the armature with the least possible loss. As will be noted in the engraving, the poles of the

field magnets, the bodies or cores of which are round in section, project upward, enclosing the armature. The armature is nearly square in longitudinal section and relatively large in diameter.

This gives a high peripheral velocity and a rapid cutting of the lines of force. In consequence of this construction, also, the armature is capable of exerting a powerful rotative force. The armature being short, avoids the use of a long and consequently less rigid shaft. The coils of the motor-magnet are wound on bobbins which are slipped over the cores; it is therefore easy to change a coil or to replace it for any purpose whatever.

The field is wound in shunt to the armature, and is relatively of a very high resistance.

This reduces the amount of electrical energy required to energize the field magnet to a very small fraction of the total electrical energy absorbed by the motor. The armature bore is thoroughly well built and is a very solid and substantial structure.

At the same time the perfect lamination of the core reduces the loss by Foucault currents to a small amount.

The winding on the armature, which is a modification of the well-known Siemens' type, is of very low resistance.

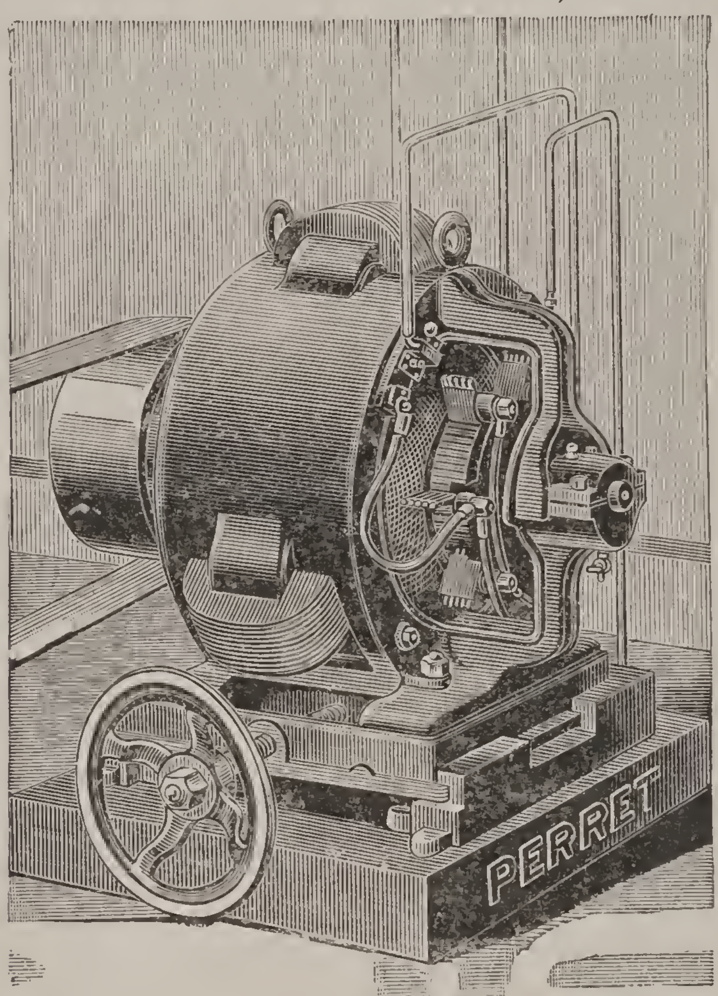
The copper wire on the armature is held in place by means of bands, which are made of such strength that it is impossible for them to yield from the centrifugal force, even when the motors are run at abnormal speed.

The Perret Motor.—The chief distinctive feature of this machine is the lamination of the field magnet. Instead of casting or forging this in several solid pieces, as is usually done, it is built of thin plates of soft charcoal iron, which are stamped directly to their finished form and clamped together by

bolts in such a manner as to secure great mechanical strength.

The advantages of such a construction are, in brief, a magnetic field of great intensity and the entire prevention of all wasteful induced currents in magnets and pole-pieces.

The armature core is also laminated, and the plates have



THE PERRET MOTOR.

teeth, which form longitudinal channels on its periphery, in which the coils are wound.

The plates in both field and armature are in the same plane, and are of soft charcoal iron, with its grain running in the direction of the line of magnetic force, and there is the least possible break in the continuity of the circuit, there being no air gap between the iron of the field and the iron teeth of the armature, except that required for clearance in rotation. Thus we have a

magnetic circuit of lowest possible resistance, and it follows from well known laws that we secure the maximum of effective magnetism with a minimum expenditure of magnetizing power.

The armature coils being practically imbedded in the armature receive the highest inductive effect from the intensely magnetized iron.

The high efficiency which such construction should give theoretically is practically demonstrated by the machines in actual work, and ranges from 70 per cent. in the smaller to 93 per cent in the larger.

Attempts have been made by many since the days of Pacinotti to use toothed armatures, but with the result that very troublesome and wasteful heating effects were produced in the solid magnets and pole pieces commonly used. With laminated field magnets these disadvantages are avoided, and we are able to secure the advantages enumerated, as well as others, among which may be mentioned the important ones, positive driving of the armature coils and less liability of winding out of balance.

It will be seen that the armature is a ring of comparatively large diameter, with longitudinal channels on its periphery, in which the conductors are wound, and thus imbedded in the iron, which is in such close proximity to the iron pole pieces that there is practically no gap in the magnetic circuit.

The field consists of three separate magnets arranged at equal distances around the armature, each magnet having two pole pieces. See Figure 160. The winding is such as to produce alternate North and South poles. The magnets are built up of plates of soft charcoal iron, which are shaped as shown in the diagram, and the magnet thus produced is of such a form that it may be readily wound in a lathe. A non-

magnetic bolt passes through a hole in each pole piece and the plates are clamped together between washers and nuts on the same. These bolts also serve to attach the magnets to the two iron end frames, which are of ring shape and are bolted to the bed plates of the machine.

The magnetic circuit is of unusually low resistance by rea-

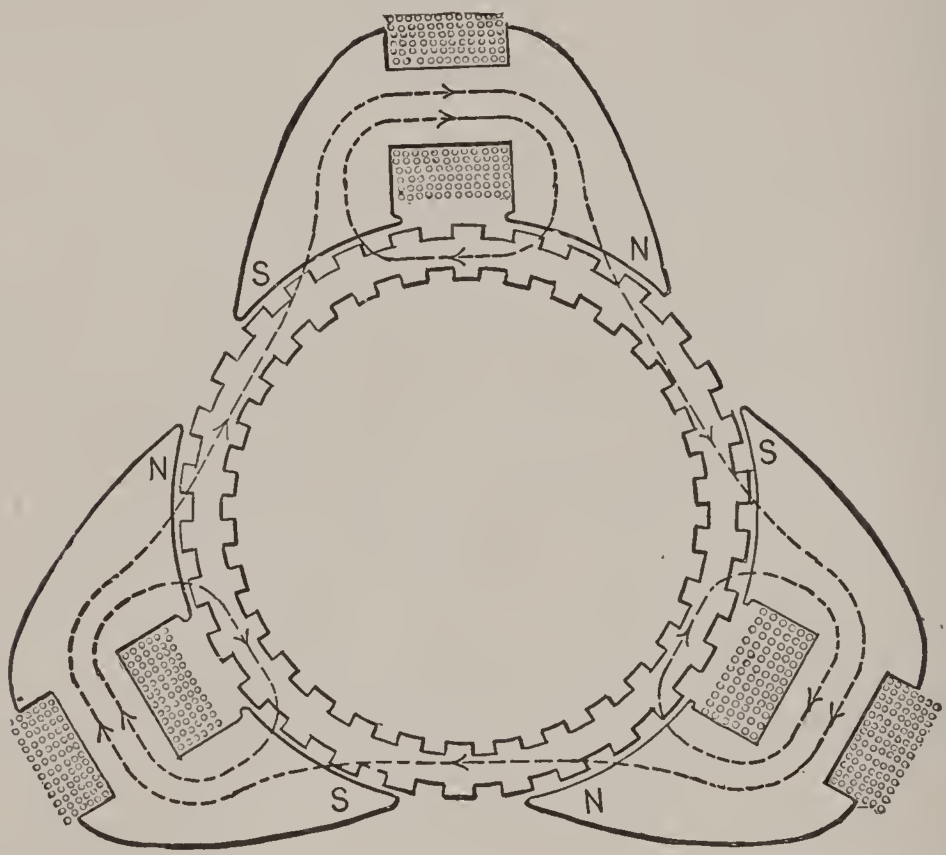


FIGURE 160.

son of its shape, its shortness, which is shown by the diagram, and the superior quality of iron used.

There is no magnetism whatever in the frame, bed or shaft of the machine, as the magnets are supported at some distance from the frame by means of the non-magnetic bolts, and the armature is mounted on the shaft by spiders of non-magnetic metal.

There is therefore no opportunity for magnetic leakage, and

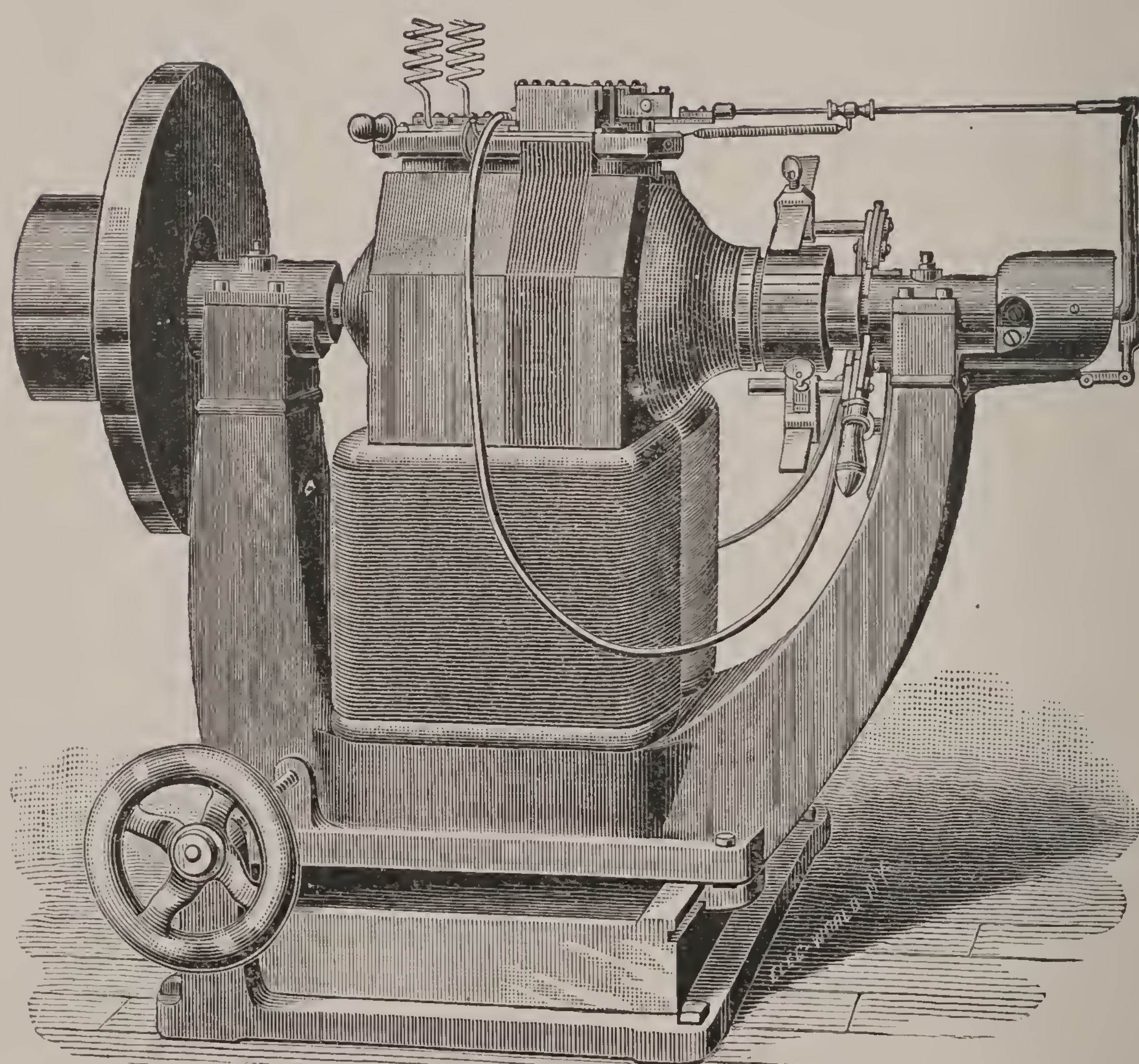
furthermore, the whole is enclosed by a shield or case of sheet metal, as shown in the illustration.

The practical advantages of low speed machines are many. For instance in ordinary machine shops, wood-work shops, printing offices, etc., the shaft is commonly run 200 to 300 revolutions per minute, and it is a simple matter to belt direct to it from a motor running 500 to 600 revolutions, thus saving the first cost of a countershaft and one belt, and saving, also, considerable power which would be lost in transmitting through the countershaft and additional belt, which would be used necessarily with a motor of high speed. The advantage is equally as great in case of elevators operated by a belt from the motor, and indeed, it is possible to gear direct from the motor to the elevator.

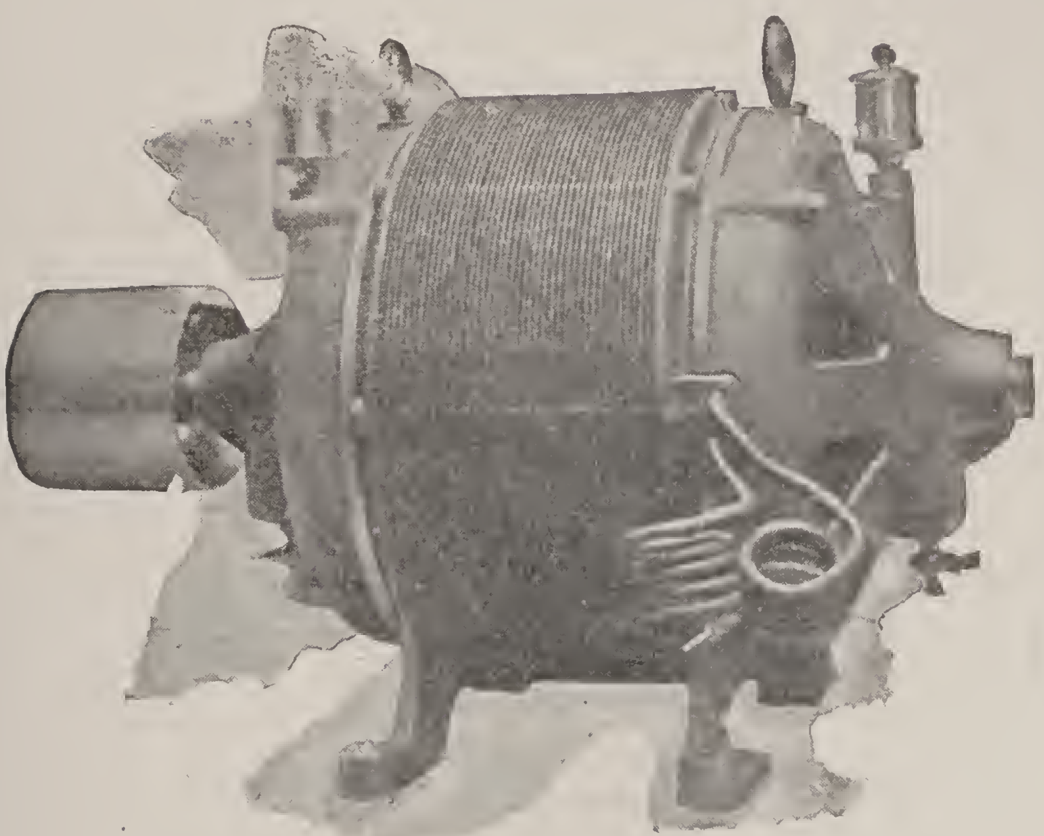
The Excelsior Motor. The engraving presented illustrates the arc light circuit or constant current motor of the Excelsior Electric Co. This motor has its armature and field magnet coils connected in series. As it is supplied with current by a generator whose electromotive force is varied by an automatic regulator to suit the demands of the motors on its circuit, it would run at a constantly increasing speed, when lightly loaded, were it not regulated and the speed kept uniform by a governing device. This consists of a centrifugal governor which controls the strength of the field magnets by cutting out the successive layers of wire in the coils as the load decreases, and cutting them in when it increases.

The two main bearings of the motor shaft and the ball and socket bearings of the governor are provided with oil chambers, from which the oil is led to the wearing surfaces by means of felt strips.

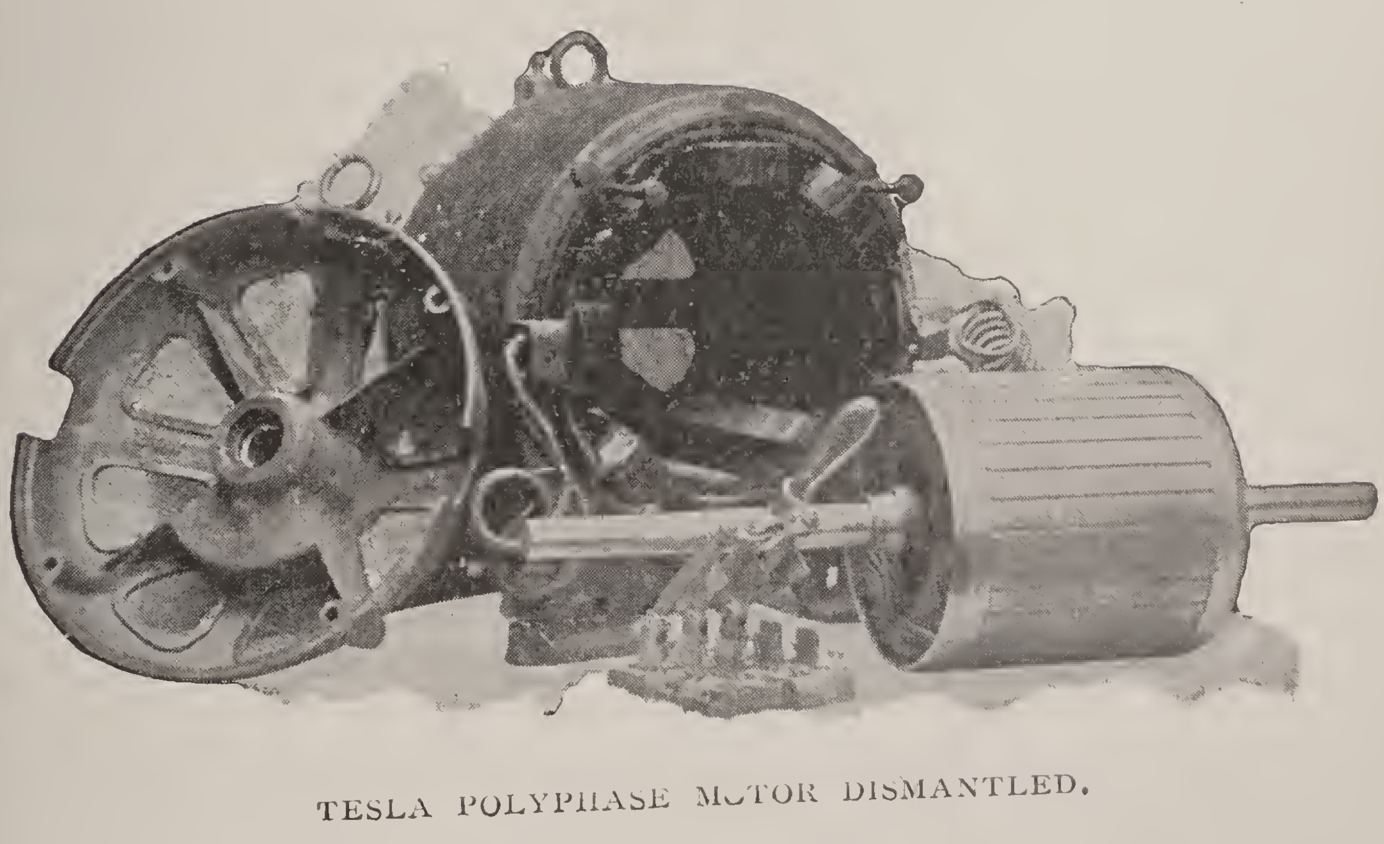
Tesla Polyphase Motor, 5 H.-P.(Rotating field type). The upper photograph, page 287, illustrates a 5-horse-power Tesla motor,



THE EXCELSIOR MOTOR.



TESLA POLYPHASE MOTOR.



TESLA POLYPHASE MOTOR DISMANTLED.

of the rotary field type, complete, while the lower photograph shows the same motor dismantled. It will be noted that the construction is such as to entirely conceal and protect against mechanical injury the coils of both field and armature. Neither commutator nor collector is used. In the Tesla motors of the two-phase type the winding of the field is made up of two distinct electrical circuits. The currents traversing these circuits differ in their phase; that is to say, the maximum strength of one current occurs at the time when the other current is a minimum, the result being rotation of the magnetism of the field. The armature is short circuited, and the currents traversing it are simply the low potential currents induced by the field. The insulation of the armature is not at any point subjected to a potential exceeding a very few volts, and it is, therefore, practically impossible to burn out this armature, while the machine may be safely operated in places so exposed to moisture as to make the use of direct current machinery impracticable. The construction of the field admits of very high insulation, and circuits carrying comparatively high potentials may be connected to it without the interposition of step-down transformers.

The starting motors used in connection with the two-wire synchronous system are of this general type, the necessary difference of phase being obtained by special methods of winding the field circuits.

CHAPTER XVII.

TYPES OF COMMERCIAL RAILWAY MOTORS.

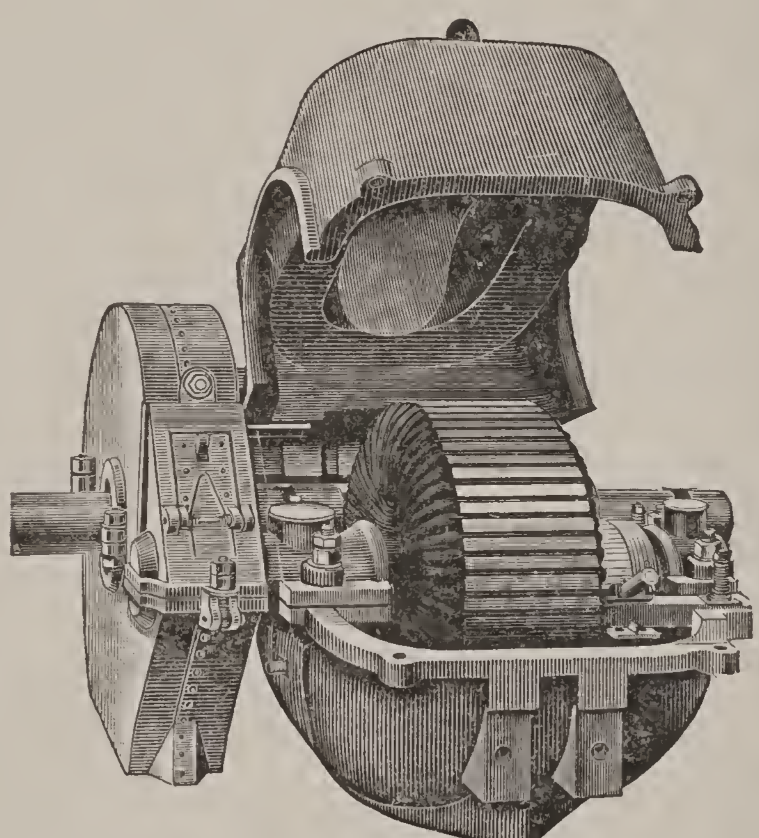
IN the construction of the electric motor for car propulsion, the motor acts simply for the transformation of electrical energy with mechanical energy. A current of electricity is sent through the armature and field magnets of a motor which causes the armature to revolve. Formerly fast speed motors were used in electric railway service, in which the armature revolved with great rapidity, necessitating the use of numerous gears and pinions by which the motion was communicated to the axle of the car. At present, slow speed motors are almost wholly used, by which the intermediate gears and pinions are left out, there being only one gear and pinion, the gear being upon the axle of the car and the pinion upon the shaft of the motor. There are, however, some exceptions to the rule. These exceptions are in gearless motors, particulars of which will be given later in this chapter. We will now call attention to the different styles of railway motors.

The Thomson-Houston W. P. Railway Motor. The accompanying illustration gives an excellent idea of this motor, which is manufactured by the General Electric Company.

The new machine embodies some decidedly novel features and its performance on the special car equipped with it was very favorably

commented upon. It is known to the trade as the W. P. motor, which being interpreted, means water-proof, and it well deserves the name, because of the particularly complete iron-clad character of the field magnets.

The figure gives a perspective view of the motor, and from it the arrangement of the iron is at once obvious. Singularly enough, it is a two-pole machine so arranged on the theory that the com-



THE THOMSON-HOUSTON W. P. RAILWAY MOTOR.

paratively slight gain in the weight efficiency that could be obtained with a multipolar type is more than offset by the increased complication of the windings. The only portions of the machine open to the outside air are exposed at the two oval openings at the ends of the armature shaft, and even these can be easily fitted with covers should such a course prove desirable. The whole magnetic circuit is composed of two castings bolted together and free to

swing apart by a hinge allowing ready access to the armature. The armature itself is nearly twenty inches in diameter, a very powerful Pacinotti-ring nearly six inches on the face and of about the same depth. It is wound with comparatively coarse wire in sixty-four sections, with fourteen turns to the section. Each coil is tightly placed in the space between two of the projecting teeth, and about the interior space the separate coils are closely packed, leaving only sufficient room for the four armed driving spider.

As will be seen, the armature takes up most of the full height of the machine, the pole pieces being but trifling projections, and the requisite cross section of iron being obtained by extending the poles to form a closely fitting iron box that appears in the exterior view.

The General Electric Company's 54 Railway Motor.—The rapid growth of passenger traffic resulting in the increasing use of heavy cars on the lines of many of the electric roads operating within city limits has induced the General Electric Company to design and manufacture a motor known as the GE–54.

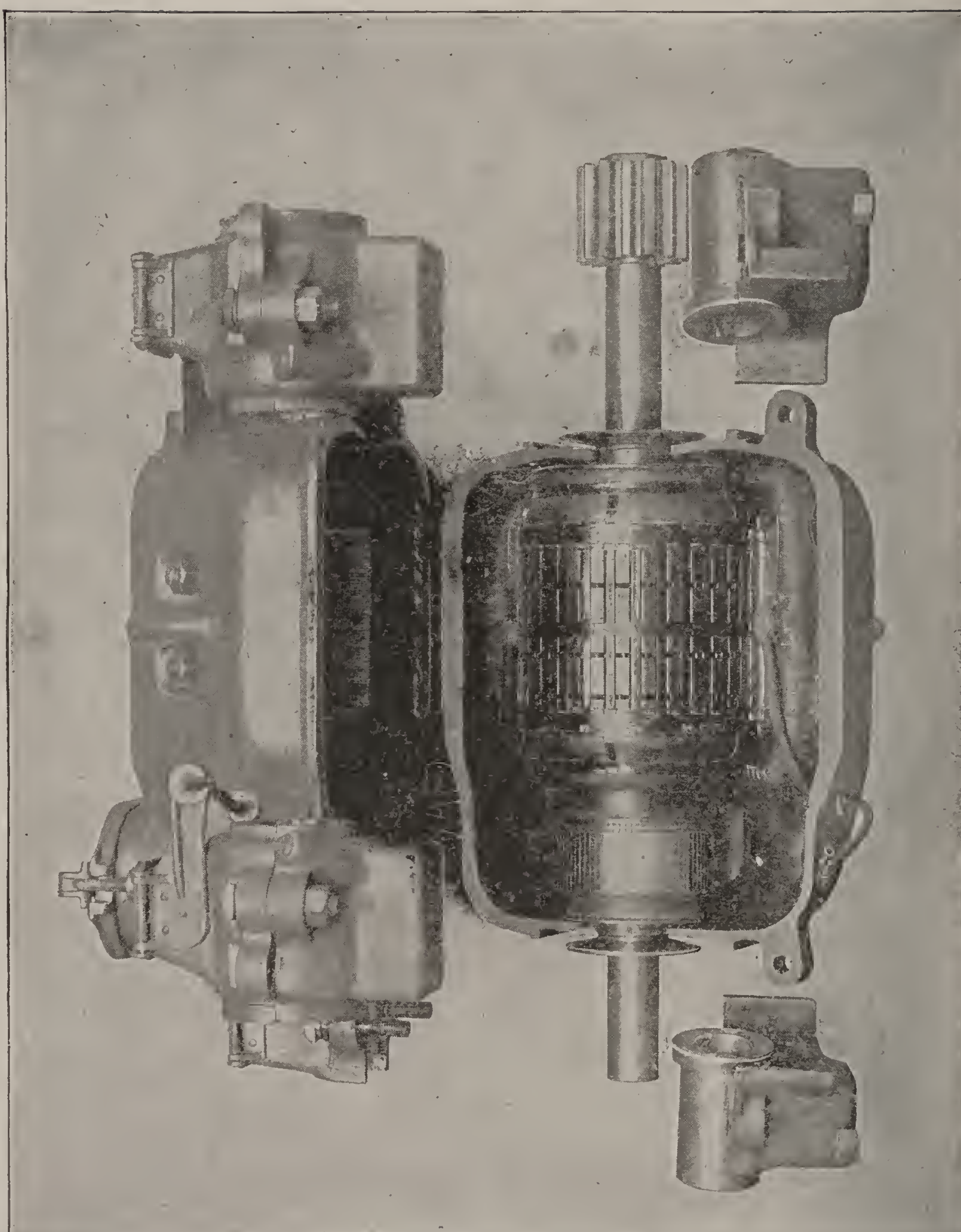
It is adapted for use on a minimum gauge of $48\frac{5}{8}''$ and in general design and construction is similar to the GE–52.

Rating.—On 500 volt circuits the GE–54 railway motor with three-turn armature will develop 25 H. P. The output is based on the standard rating; that is, a maximum rise of 75° C. in the temperature of this winding after a run of one hour at full rated load, the temperature of the surrounding air not exceeding 25° C.

Magnet Frame.—The magnet frame is in the form of a hexagon with well rounded corners, and is cast in two pieces of soft steel of high magnetic permeability. The two castings are bolted together, but the front bolts are hinged in order that the lower frame may be swung down conveniently so as to permit inspection or repairs of the field or armature.

There is an opening in the frame just over the commutator large enough to provide for the removal of the brush holders and brush holder yoke and also to permit of inspection of the commutator and brush holders. The cover, which is of malleable iron, is held in place by an adjustable cam locking device, and can be readily removed when necessary. The lower frame has a small opening directly under the commutator, also protected by a suitable cover.

Pole Pieces and Field Coils.—The pole pieces are built up from thin soft iron laminations, riveted together, and bolted to the frame by through bolts with nuts on the outside.



LOWER FRAME DROPPED — SHOWING ARMATURE READY FOR REMOVAL.

The four field coils are placed at an angle of 45° from the horizontal, and are held in place by pressed steel flanges or spool holders which are clamped to the pole pieces. The coils are made of asbestos, cotton covered wire, and are further insulated with wrappings of varnished cloth and tape. The insulation on the coils is subjected to a high potential test of 4000 volts alternating current.

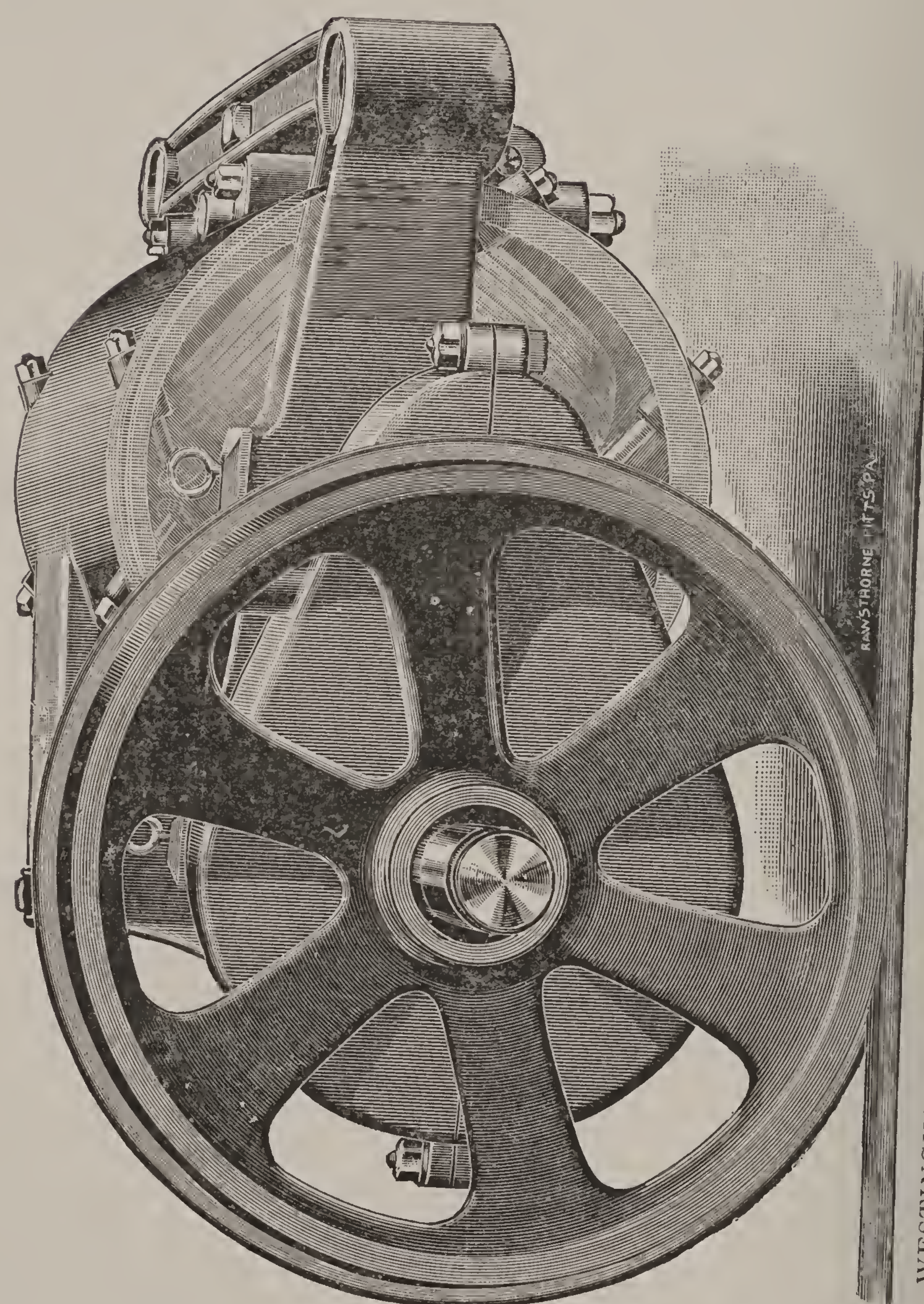
Armature.— The armature is of the ironclad type, and the core is built up of thin soft iron laminations which are carefully japanned and securely keyed to the shaft. The laminations are clamped at each end by cast-iron heads which are also keyed to the shaft. The core is hollow, and is ventilated by the air which enters the pinion end of the core, and passes out through the air ducts placed at regular intervals among the laminations.

The armature winding is of the series drum type, the number of turns per coil varying with the requirements of each case. The coils are made up in sets; and, before being placed in the slots of the armature core, each set is formed, and thoroughly insulated with specially prepared tape and cloth which have high insulating qualities and are practically impervious to moisture.

The terminals of each coil are brought directly to the commutator segments, and soldered so as to properly connect the coils to each other and at the same time form the connections between the windings and the commutator.

The Westinghouse Four-pole Single-Reduction Street Railway Motor. — A view of the motor is shown on page 294, bringing out more prominently the gear casing. The construction of the motor can be readily comprehended by referring to the view. Here are shown the castings complete of the motor, consisting of only three parts — the frame and the two semi-cylinders, the two latter being practically one. The size of the frame is such that it can be placed upon a bogie-truck, being equally well adapted for an eight-wheel as for a four-wheel car. The width of the motor is such that it can be used on a 3 feet 6 inch gauge. In the sides of the two semi-cylinders are seen the holes where the plates are secured, which serve as a protection to the sides of the machine.

If it is necessary, the machine can be entirely shut in. It was formerly believed that a motor could not be thus enclosed, since it needed ventilation; but experience with slow speed motors has demonstrated that if a motor has been correctly



WESTINGHOUSE FOUR-POLE SINGLE-REDUCTION STREET RAILWAY MOTOR.

designed, electrically and mechanically, and properly constructed, there is no difficulty whatever in enclosing it. At the same time, if, in some cases, it be deemed advisable to allow a small opening for ventilation, the plates can be constructed accordingly.

This method of enclosing the motor is exceedingly convenient in rain and snow storms, and especially where the cars pass over trestles which expose the motor. Heretofore, considerable trouble has been experienced from water dripping on the motor through the car floor. In this motor, as is obvious, such troubles are eliminated. Again, the objections to a motor being exposed to water, dirt and dust, can be appreciated when it is remembered that a large number of engineers favor some method of mounting the motor on the car floor. The above objections are overcome by making the motor ironclad. By again referring to the view there will be seen the four internal poles; hence it is called a four-pole motor. Some of the advantages of a four-pole motor over a two-pole machine, are: slower speed; great simplicity; more symmetrical; and a greater radiating surface for the field coils. In case a two-pole motor is used, and the same amount of wire is wound about these two poles, the radiating surface is far less than where there are four poles.

Another important feature to be noticed is the form of the motor proper; namely, circular. It is a well known law in mechanics that the strongest form is the arch; consequently, by this cylindrical form, we obtain the maximum strength with the minimum amount of material. All corners and sharp edges which mean unnecessary weight, and at the same time having a tendency to reduce the efficiency, are eliminated from this machine. The fields are enclosed and protected, not merely externally by

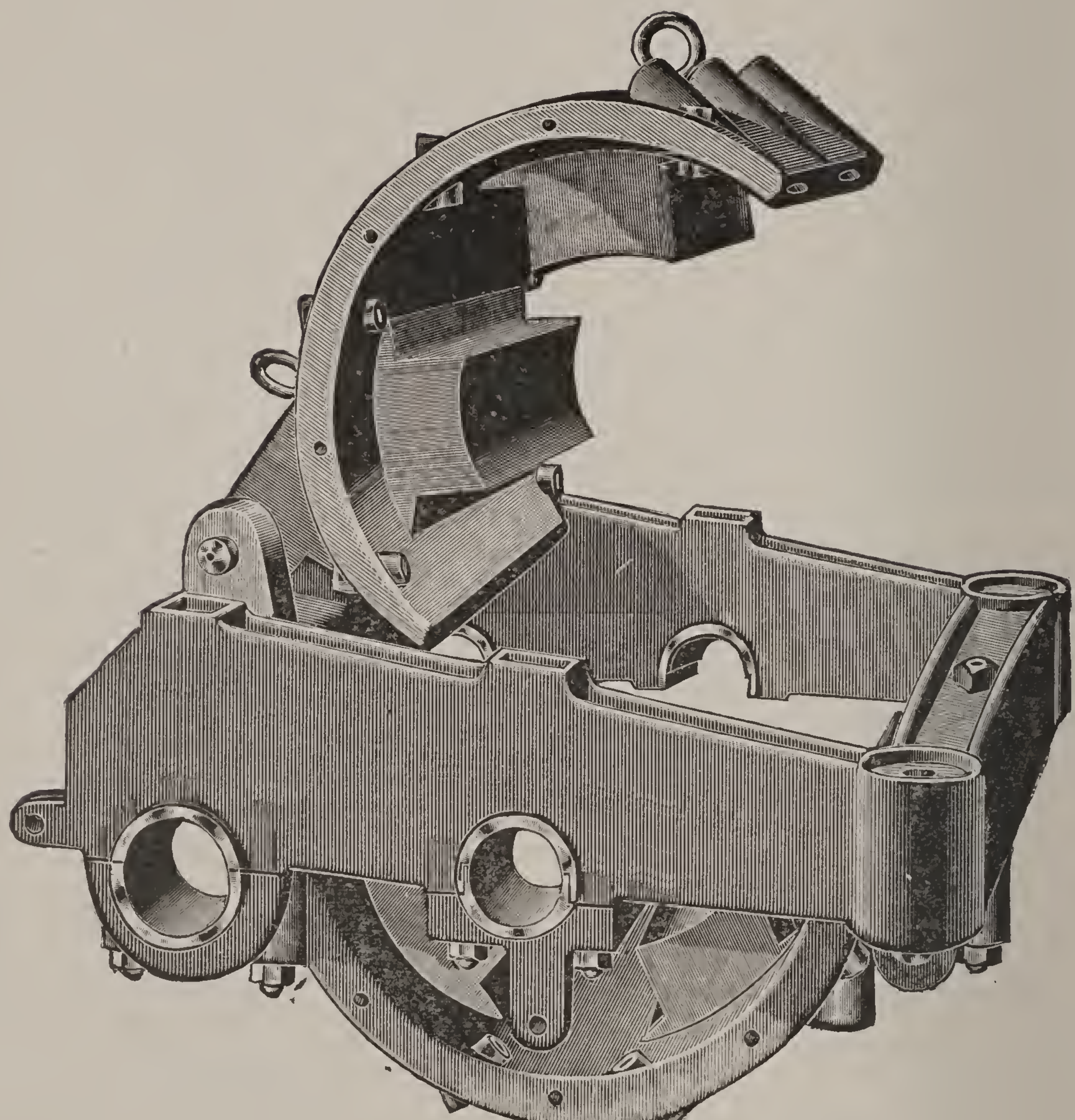


FIGURE 161.

the surrounding cylindrical shell, but also internally by a heavy brass cap. There is no liability to accident in case they strike any obstruction in the road, neither can they be injured by gross carelessness in handling.

The cast iron frame on which the motor is mounted, forms a distinguishing feature of the Westinghouse machine. The frame is rectangular, in one casting, and made strong at points subjected to the greatest strains. Special machinery has been devised for boring out the holes for bushings, so that the frame, and, in fact, all parts of the motor, are interchangeable. By means of this frame the armature shaft and car axle are maintained in alignment, and consequently perfect meshing of the gears is obtained, which experience has proved to be of importance.

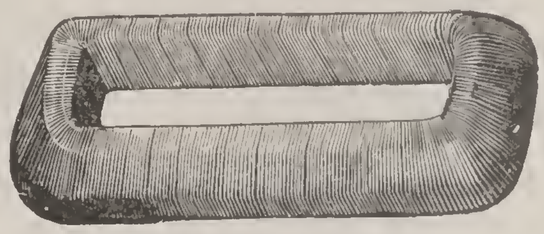


FIGURE 162.

The gearing is mounted closely to the frame, so as to avoid the objectionable buckling and tendency to loosen the moving parts. This method gives a strong mounting and perfect rigidity between the parts of the motor. Moreover, by extending this frame around the motor and suspending it at both corners, we distribute the strains and prevent the abnormal wearing of the bearings, so characteristic of center suspension.

The illustration, see Figure 161, shows the method of hinging the field castings. These, as will be noticed, can be swung back, giving easy access to the fields and armature. It will be observed that the poles protrude radially from the interior of the

cylindrical shell. The field coils, one of which is shown in Figure 162, are slipped over these poles, held in position and at the same time protected from the interior by a brass cap. The ease with which the fields can be removed or replaced needs but a glance to be understood. Any field can be removed without disturbing any other part of the motor, and this can be accomplished in little time. The lower fields can be similarly changed by swinging back the lower semi-cylinder. The armature is then ready to be taken out, and by taking off the brushing cap and placing a sling about the armature, it can be lowered into the pit without obstruction or danger of injuring the same.

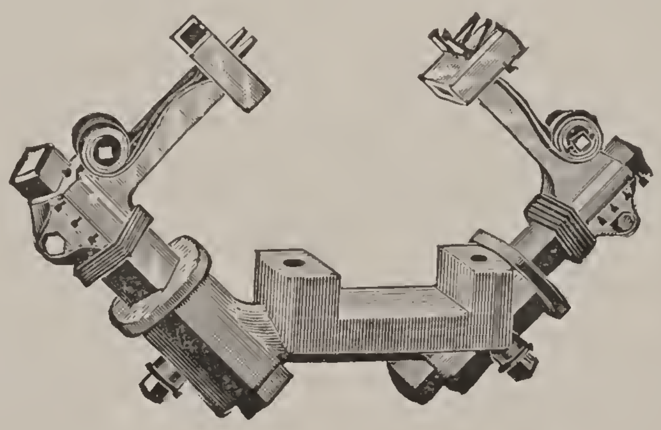


FIGURE 163.

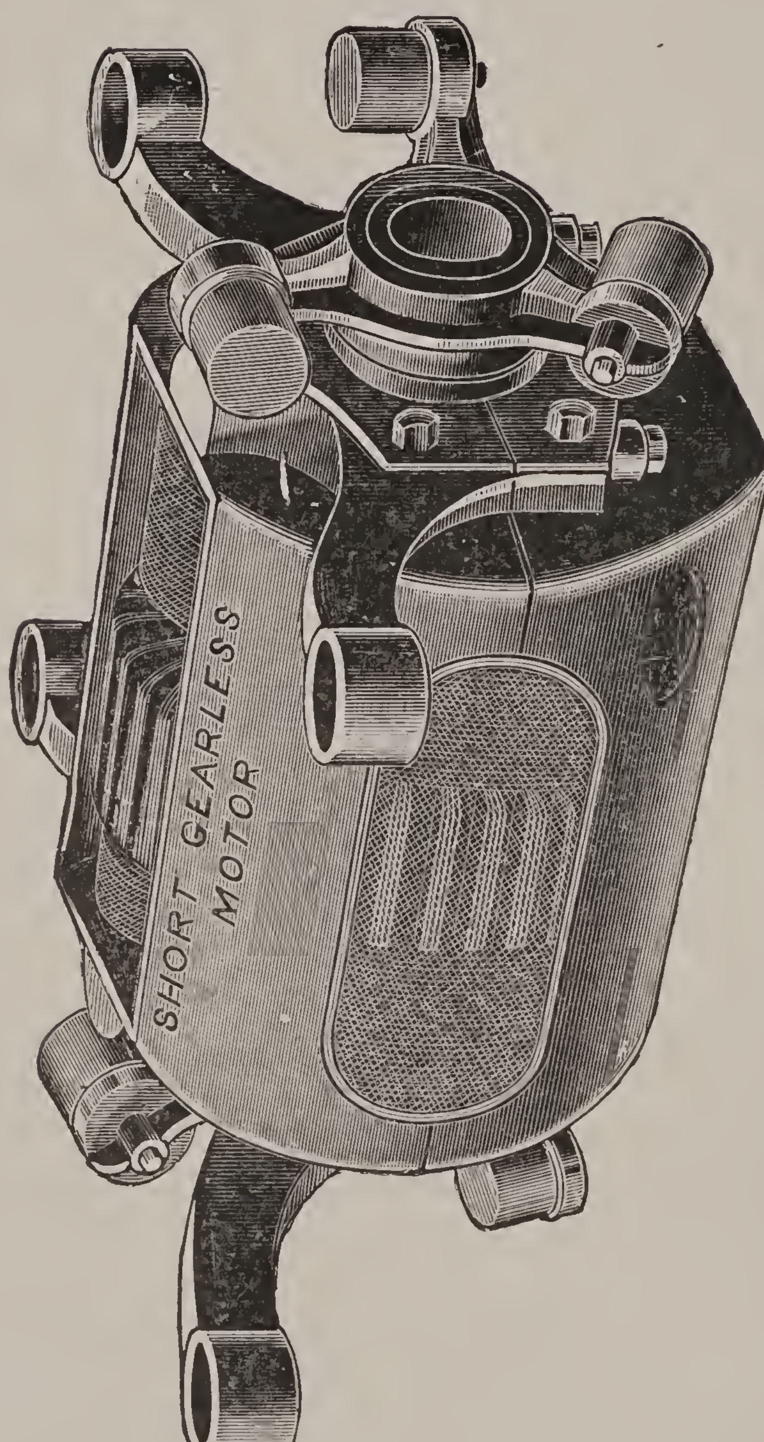
The armature is what is known as the drum type, which experience has demonstrated to be superior to other types for street railway work. The armature core is built up of laminated grooved iron plates, so that the completed core has slots to receive the wires. In the armature the wires are imbedded in iron, hence they cannot be injured from ordinary external causes. Since the surface of the armature is iron, the air space, that is, the distance between the iron of the armature and the pole pieces is reduced to a minimum, increasing the efficiency of the motor.

The armature shaft is manufactured from the best grade of

forged steel, especially prepared for this purpose. The construction of the shaft and armature make it exceedingly strong, and capable of withstanding the severe strains sometimes brought upon it. In looking at the frame, it will be noticed that the oil receptacles are sunk into the same. These oil receptacles are so placed that there is no possibility of injuring them. It is worthy of attention that these facilities for oiling are excellent. The oil boxes are large, and the method of oiling is the same as that of the high speed motor, with which they have never had a hot box, so that it can be said with confidence no trouble will be experienced from this source with their slow speed motor.

The field coils are wound with wire having exceedingly large carrying capacity. The arrangement adopted for the brush holder see Figure 163, has also been carefully worked out. It consists of a square oak holder attached to the side of the frame, and carrying the brush-holders proper, which are clamped so that they can readily be adjusted. The carbon brushes are placed in a sliding frame, and pressed against the commutator by a pair of springs, which can be released by a pressure of the finger, and the carbon slipped out for replacement when worn. The casting supporting the brush holder is fastened to the bottom of the motor frame, so that the brushes rest on the upper part of the commutator, the greater part of which is exposed above so that the commutator can be cleaned from the inside as well as from the outside of the car.

The Short Gearless Motor. The gearless motor (designed by the Short Company) is shown on page 300. Referring to the machine in a general way, it is seen that all gearing is absolutely eliminated, the number of bearings is reduced to two on each motor and four in the equipment. The armature speed comes down to



THE SHORT GEARLESS MOTOR.

the minimum, namely, that of the car axles in practical operation. The noise of gearing and brushes is entirely obviated, and there are but three wearing parts on each motor. The intensity of the magnetic field is now at its maximum; this effect being due, not to a material increase in the weight of armature and pole pieces, but to the wholly different method of construction, Instead of two magnets we find eight; instead of a wide magnetic gap, we find one extremely narrow, with consequently great intensity of the "field of force." Instead of a drum armature of small diameter, we find a ring armature of comparatively large diameter, and increased "leverage;" the sum total being that we have here in full measure a motor of the second type, namely, one with an armature revolving at low speed in an intense "magnetic field," exerting a power fully equal to the motor with gearing, and at a considerable less expenditure of current since all friction of gearing is eliminated.

The motor is complete in itself. It is not keyed to the car axle, nor does it touch at any point. The motor as a whole can be taken off the car axle after removing a wheel, but in practice it will rarely or never be found necessary to do this. A plan of the 15 horse power gearless motor is shown in Figure 164. A sectional view is shown in Figure 165.

The field magnets are eight in number, four on each side of the armature. They face each other at a distance of only ten inches and thus form a most intense magnetic field. The magnets are bolted to the framework of the motor, in the center of which are the bearings which carry the hollow armature shaft. (See Figure 166.) The double arms running out from the framework to the cross girders on the truck make provision for the support of the entire motor. The insulation between

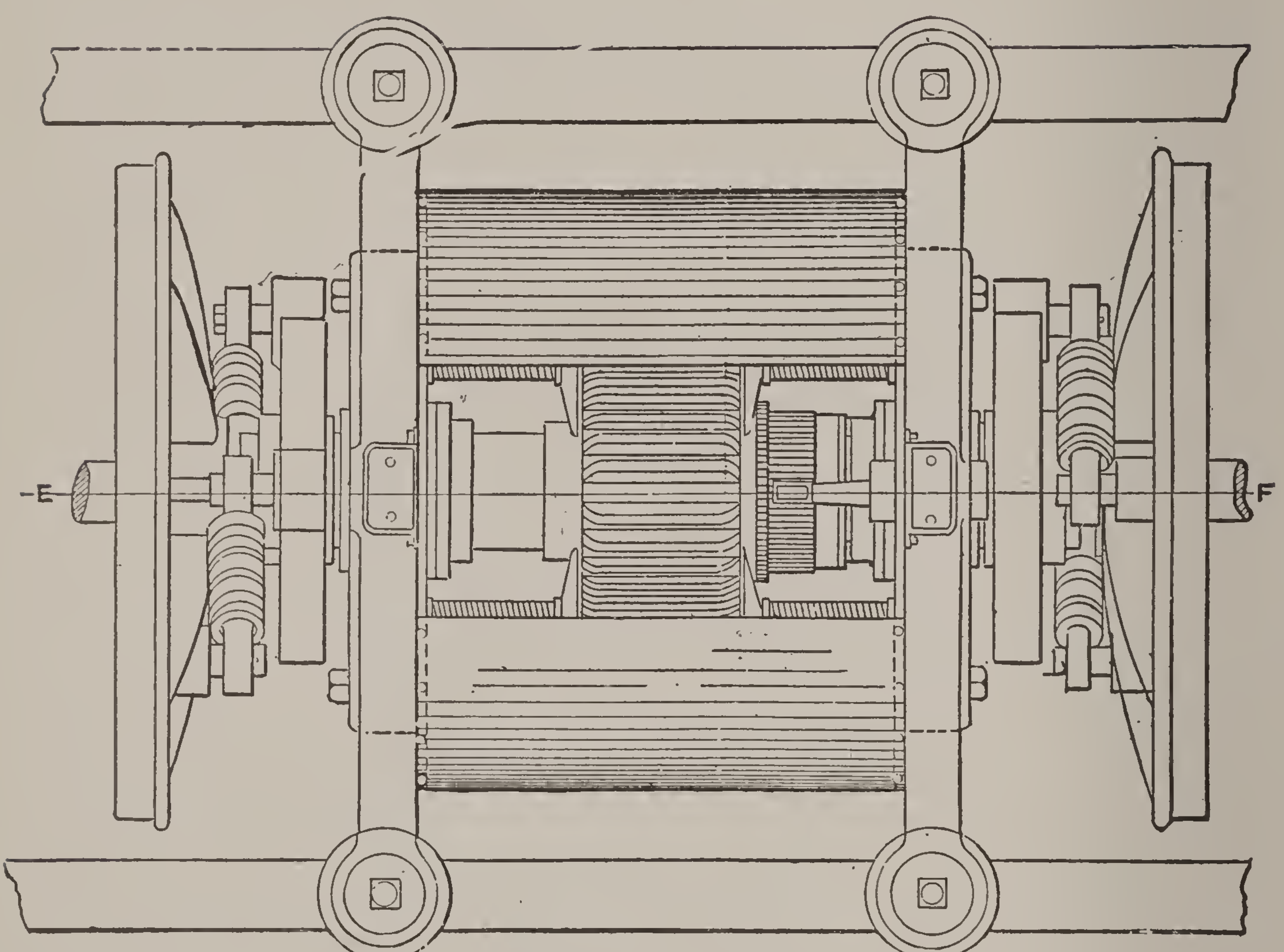
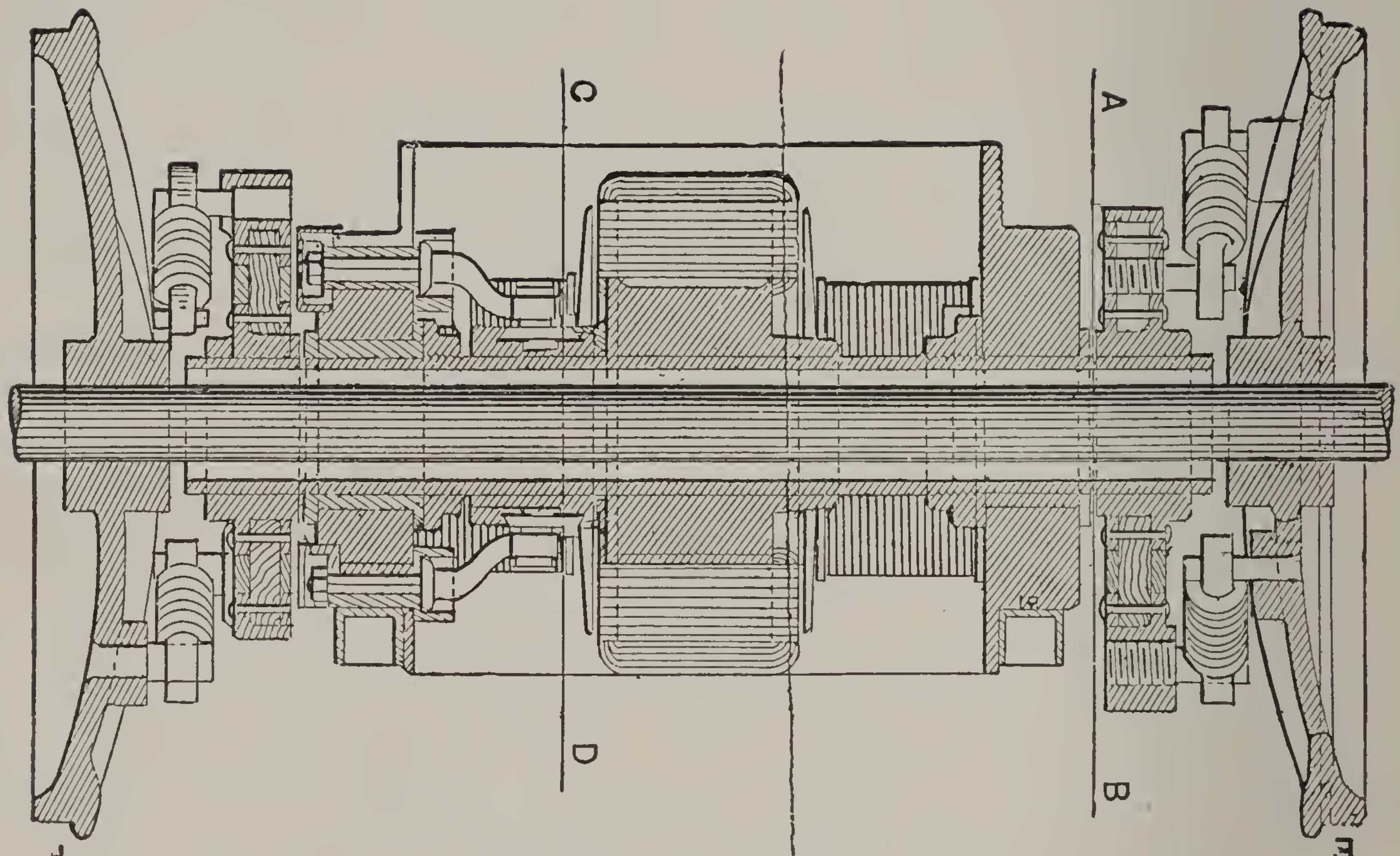


FIGURE 164.

these brackets and the girders is provided by means of heavy rubber bushings through which pass the bolts. By removing the bolts attaching the fields to the supporting framework, the coils may be quickly taken out, either for repair or to more easily get at the armature.

The armature is keyed to a hollow steel shaft, which is concentric with the axle of the truck, an inside clearance of one inch all around being provided for. The armature proper consists of a laminated iron core upon which are mounted separate and entirely independent coils, following the well-known methods of the Short double reduction type of motor. These coils are perfectly ventilated, and in past practice almost no trouble has been experienced from burn-outs. It is the one street car armature at present constructed of which it can be truly said that the coils are *absolutely independent*, and can be separately rewound in case of accident, at almost nominal expense. Mounted upon the hollow shaft, close to the armature, is the commutator, which is protected from injury by the surrounding pole pieces. The commutator is massive in construction and of large diameter, the idea being that, because of its massiveness and slow speed, the wear will be reduced to a minimum, and the replacing of the commutator will occur only at long intervals. On the ends of the hollow shaft are mounted two discs fastened thereto, the peripheries of which are insulated from the hubs by the special wooden web construction. Between the commutator and the disc on the one side and the armature and the second disc on the other, are the bearings, which are carried by the motor frame.

It has been before said that the motor has no connection whatever with the car axles; it follows, therefore, that it is nec-



THE GEARLESS MOTOR — 15 H P. — Section.

FIGURE 165.

essary to provide means of propelling the car by making some attachment between the hollow armature shaft and the wheels. This is done very simply by means of heavy coiled springs, which extend from the peripheries of the armature shaft discs to bosses on the wheels. Position and attachment of these springs are shown in Figure 167. They are of great strength, and can pull a very heavy weight with but slight extension or compres-

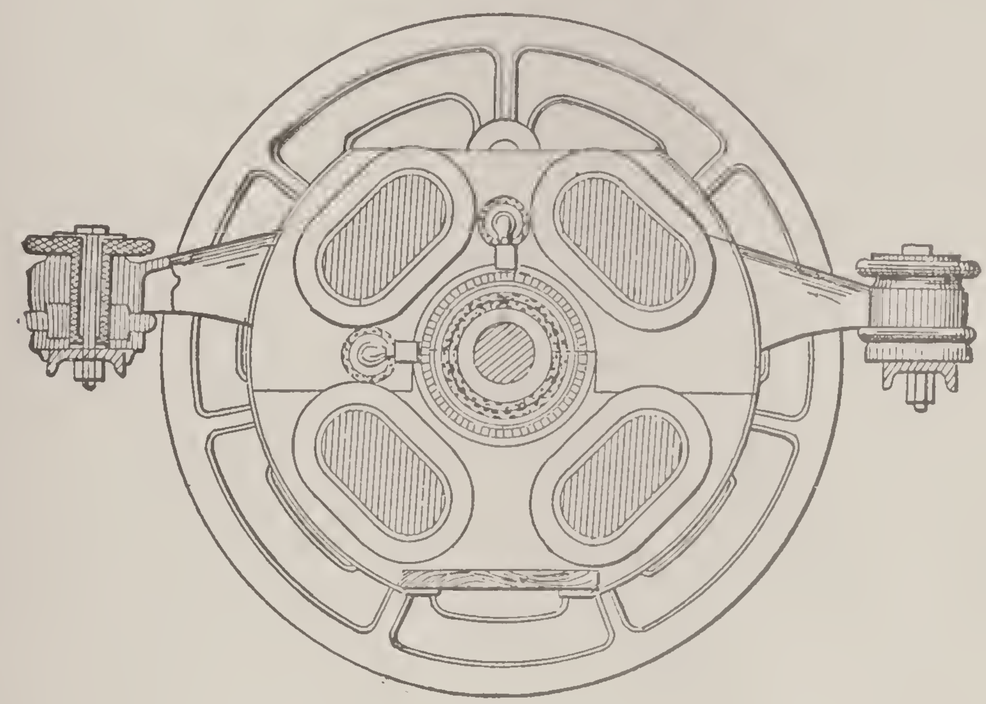


FIGURE 166.

sion. As they are attached to both disc and wheel upon circles of the same radius, their effort is a nearly direct circumferential pull.

From the description above it is at once apparent that the entire motor is absolutely insulated from the truck at every point. This is a feature which we believe to be of great importance. By this means leakage or accidental connection between field or armature circuits and the iron frame work (which may be caused by moisture, dust, dirt, etc.), does not produce a "ground circuit,"

and consequent burn-out of field or armature coil, as is the case with other types of machines.

To protect the motor from dust, moisture, etc., which have been a potent source of trouble in other forms of equipment, an iron case completely encloses the motor, except at the top, where necessary ventilation is provided, and is water-tight up to the axles. To get at the motor, it is only necessary to unlatch one end of the casing and swing it down and out away from the mechanism.

FIGURE 167.

The dimensions of the motor are as follows: From the center of the axle to the bottom of the casing is 12¾ inches. On a 36-inch wheel which we strongly advise, not only in the gearless, but in other types of motor, there is thus a clearance of 5¼ inches which is ample for all purposes. At a speed of ten miles an hour, the armature revolves at 94 revolutions per minute, with a 36-inch wheel. The equivalent speed of the single reduction motor would be at least 400, and of a double reduction motor about 1,200. One of the most valuable features of the

machine is the facility with which it can be repaired in case of necessity. By loosening four bolts in the motor framework, and by taking off the iron strips below the wheel boxes, one end of the car may be jacked up, and the axle wheels and armature complete run out from under, into the light of day. The armature coils may be rewound without removing the armature from the car axle. Field coils can be repaired as easily. The commutator may be reached and dressed while the machine is running. If steel tired wheels are used by a special arrangement the motor may be jacked up, raising the wheels from the ground, current brought to the motor, and the wheels turned just as would be the case on the truck, so that by a special "tool-jig" the wheels may be turned down as required, thus removing any flat spots or imperfections. Or the wheels and axles may be turned from outside through the hollow shaft of armature, without the least effect on motor, it being, of course, necessary, however, to remove the spring attachment between the hollow shaft discs and the wheels. In case it is found necessary to replace a commutator, a wheel must be pressed off and the commutator removed bodily. This could be done only with great difficulty if the armature were keyed directly to the axle instead of being on the hollow shaft. The commutator will have a life three or four times that of the wheels in common use on electric railways, and it will not usually be necessary to press off a wheel for the express purpose of replacing a commutator.

APPENDIX A.

MANAGEMENT OF DYNAMOS AND MOTORS.

Location.—Proper care and good management are necessary for the success of any dynamo or motor. Cleanliness is of great importance; much trouble is caused by its neglect. A dynamo or motor should be firmly set on a solid foundation: this is especially important with large machines, for if the foundation is poor, the vibrations caused by the rotation of the armature may damage the machine in many ways. The iron base of a dynamo or motor should always be insulated from the foundation to prevent a ground. A dynamo or motor should always be located in a dry place. Especially avoid a location near where grinding, filing or turning is being done, as the filings, chips or dust from such work, may fly on the machine and injure the armature or commutator. Also in selecting the location, leave room enough to inspect and make any necessary repairs to the machine or to remove the armature.

Starting the Dynamo.—First make sure that the machine is perfectly clean; that no screws or parts are loose; that all bearings are properly oiled and that the oil cups have a sufficient supply of oil in them; the brushes set at the proper point and the circuit left open. Now start the dynamo with care and gradually bring it to full speed. If anything appears

to be wrong shut the machine down instantly, find and remedy the trouble before starting again.

Starting Motors.—The same care must be observed in starting motors as that used with dynamos. The operation is simple as it only consists in operating a switch. Both a switch and a rheostat is generally used for starting and stopping "shunt" or compound wound motors. The use of a rheostat is for taking care of the current in the armature, the resistance of the armature being very low in order to get high efficiency and constant speed, and the quantity of current going through it in starting might be a great many times more than its normal numbers of amperes, hence this "resistance" or rheostat is interposed, in the external circuit, between the motor and switch.

Dynamo Fails to Generate.—This trouble may arise from a number of causes; it may be located in the machine or in the external circuit. If in the machine it may be caused by a short circuit in the armature or pole pieces, if so the trouble must be located and the armature or pole piece rewound. It may be caused by a poor connection or broken wire in the machine, or by the brushes not being in contact with the commutator. Another cause is residual magnetism too weak or destroyed, due to proximity to another dynamo, or a jar to the machine. The remedy is to remagnetize the pole pieces by sending a current through the field coils from a battery or another dynamo. If this fails, reverse the direction of the current, as the trouble may be caused by the magnets having enough polarity to prevent the current building them up when sent in the direction first tried. Another cause is, not having the brushes in proper position. If the trouble is outside the machine it may be caused by an open circuit, *i.e.*, an open

switch, a burnt out fuse, a broken wire or brushes not touching commutator; look after these things carefully.

Sparking at Commutator.—Too much sparking at the commutator may be due to: Brushes not set at the neutral point, by the machine being overloaded, by a rough commutator, by a short circuit, a broken circuit, a ground in the armature, or by brushes in poor contact with commutator. Examine the machine carefully, find the cause, and remedy it accordingly. A brush should never be lifted from the commutator while the machine is running; it will cause an arc and make a bad spot on the commutator. Only a gentle pressure of the brushes on the commutator is required; the brush holder springs should allow a certain amount of flexibility in order to prevent sparking.

Bad Commutators.—The commutator is one of the most sensitive parts of the dynamo or motor; it should always be kept smooth. When a commutator gets rough it may be made smooth by the use of emery cloth, or fine sand paper. Either of these may be wrapped around a block of wood and pressed against the commutator, taking care to raise the brushes before the operation; it should never be done while the dynamo is at work. Great care must be taken to clean off any sand or emery dust that may remain upon the commutator, brushes or shaft, as it will cut the surface of them for a long time, and might cause serious damage. For spots and grooves on commutator there is no remedy but turning in the lathe. Files should never be used; it is quite impossible to produce a true cylinder with them.

Hints for Running Dynamos and Motors. — Keep iron and steel tools away from the machine while running and never file near it. Iron and steel tools and filings are liable to be drawn

by the magnetism into the machine and damage it. For this reason use brass or zinc oil cans for lubricating. Do not spill oil or water upon a dynamo, and have shields to prevent adjacent machinery from spattering oil upon it. Have a pair of bellows to blow the dust from the commutator and armature coils of the machine. Oil is an insulator, therefore very little of it should be used upon the commutator; a few drops rubbed on with the hand is sufficient. For the sake of personal safety it is a good plan to wear rubber boots and thick rubber gloves when at work around circuits of 500 volts and upwards. Rubber covers are now made for the handles of all iron and steel tools which every electrician should use. Touch the bearings and field-coils occasionally to see if they are hot. To ascertain if the armature is heated, place the hand in the current of air thrown out from the machine by its centrifugal force. Be careful and not overload the machine, as more troubles arise from this than any other cause.

Conclusion.—The author has not attempted to point out all the troubles and their remedies to which the dynamo or motor is heir, but thinks he has shown a sufficient number to give the reader a fair understanding of how to successfully manage small machines. For further information upon the subject, we would refer the reader to the excellent work "Practical Management of Dynamos and Motors," by Crocker & Wheeler.

APPENDIX B.

TABLE SHOWING THE DIFFERENCE BETWEEN WIRE GAUGES.

No.	New British.	London.	Stubs'.	Brown & Sharpe's.
0000	.400	.454	.454	.460
000	.372	.425	.425	.40964
00	.348	.380	.380	.36480
0	.324	.340	.340	.32495
1	.300	.300	.300	.28930
2	.276	.284	.284	.25763
3	.252	.259	.259	.22942
4	.232	.238	.238	.20431
5	.212	.220	.220	.18194
6	.193	.203	.203	.16202
7	.176	.180	.180	.14428
8	.160	.165	.165	.12849
9	.144	.148	.148	.11443
10	.128	.134	.134	.10189
11	.116	.120	.120	.09074
12	.104	.109	.109	.08081
13	.092	.095	.095	.07196
14	.080	.083	.083	.06408
15	.072	.072	.072	.05706
16	.064	.065	.065	.05082
17	.056	.058	.058	.04525
18	.048	.049	.049	.04030
19	.040	.040	.042	.03589
20	.036	.035	.035	.03196
21	.032	.0315	.032	.02846
22	.028	.0295	.028	.025347
23	.024	.027	.025	.022571
24	.022	.025	.022	.0201
25	.020	.023	.023	.0179
26	.018	.0105	.018	.01594
27	.0164	.01875	.016	.014195
28	.0148	.0165	.014	.012641
29	.0136	.0155	.013	.011257
30	.0124	.01375	.012	.010025
31	.0116	.01225	.010	.008928
32	.0108	.01125	.009	.00795
33	.0100	.01025	.008	.00708
34	.0092	.0095	.007	.0063
35	.0084	.009	.005	.00561
36	.0075	.0075	.004	.005

Table of Different Gauges, with their Diameters and Areas in Mils.

STANDARD.			AMERICAN.			BIRMINGHAM.		
No of Gauge.	Diameter in Mils.	Area in C M=d²	No. of Gauge.	Diameter in Mils.	Area in C M=d²	No. of Gauge.	Diameter in Mils	Area in C M=d²
7-0	500	250000						
6-0	464	215296	4-0	4600	211600			
5-0	432	186824				4-0	454	206116
4-0	400	160000	3-0	4096	167805	3-0	425	180625
3-0	372	138384	2-0	3648	133079			
2-0	348	121104				2-0	380	144400
0	324	104976	0	3249	105592	0	340	115600
1	300	90000						
2	276	76176	1	2893	83694	1	300	90000
3	252	63504	2	2576	66373	2	284	80656
4	232	53824	3	2294	52634	3	259	67081
5	212	44944				4	238	56644
6	192	36864	4	2043	41742	5	220	48400
7	176	30976	5	1819	33102	6	203	41209
8	160	25600	6	162	26244	7	180	32400
9	144	20736	7	1443	20822	8	165	27225
10	128	16384	8	1285	16512	9	148	21904
						10	134	17956

Table of Different Gauges, with their Diameters and Areas in Mils.

STANDARD.			AMERICAN.			BIRMINGHAM.		
No. of Gauge.	Diameter in Mils.	Area in C M=d²	No. of Gauge.	Diameter in Mils.	Area in C M=d²	No. of Gauge.	Diameter in Mils.	Area in C M=d²
11	116	13456	9	1144	13110	11	120	14400
12	104	10816	10	1019	10381	12	109	11881
13	092	8464	11	0907	8226	13	095	9025
14	080	6400	12	0808	6528	14	083	6889
15	072	5184	13	072	5184	15	072	5184
16	064	4096	14	0641	4110	16	065	4225
17	056	3136	15	0571	3260	17	058	3364
18	048	2304	16	0508	2581	18	049	2401
			17	.0452	2044	19	042	1764
19	040	1600	18	0403	1624			
20	036	1296	19	0359	1253	20	035	1225
21	032	1024	20	032	1024	21	032	1024
22	028	784	21	0285	820	22	028	784
23	024	576	22	0253	626	23	025	625
24	022	484	23	0226	510	24	022	484
25	020	400	24	0201	404	25	020	400
26	018	324	25	0179	320	26	018	324

Table of Dimensions and Resistances of Pure Copper Wire.*

REVISED.

No. B. & S.	Diam. Mils.	Area. Circular Mils.	Area. Square Inches.	W'gt & Length. Sp. gr. 8.9 Lbs. per 1000 ft.	Pounds per mile.	Feet per pound.
0000	460.000	211600.0	166190.2	640.73	3383.04	1.56
000	409.640	167805.0	131793.7	508.12	2682.85	1.97
00	364.800	133079.0	104520.0	402.97	2127.66	2.48
0	324.950	105592.5	82932.2	319.74	1688.20	3.13
1	289.300	83694.5	65733.5	253.43	1338.10	3.95
2	257.630	66373.2	52129.4	200.98	1061.17	4.98
3	229.420	52633.5	41338.3	159.38	841.50	6.28
4	204.310	41742.6	32784.5	126 40	667.38	7.91
5	181.940	33102.2	25998.4	100.23	529.23	9.98
6	162.020	26250.5	20617.1	79.49	419.69	12.58
7	144.280	20816.7	16349.4	63.03	332.82	15.86
8	128.490	16509.7	12966.7	49.99	263.96	20.00
9	114.430	13094.2	10284.2	39.65	209.35	25.22
10	101.890	10381.6	8153.67	31.44	165.98	31.81
11	90.742	8234.11	6467.06	24.93	131.65	40.11
12	80.808	6529.94	5128.60	19.77	104.40	50.58
13	71.961	5178.39	4067.09	15.68	82.792	63.78
14	64.084	4106.76	3225.44	12.44	65.658	80.42
15	57.068	3256.76	2557.85	9.86	52.069	101.40
16	50.820	2582.67	2028.43	7.82	41.292	127.87
17	45.257	2048.20	1608.65	6.20	32.746	161.24
18	40.303	1624.33	1275.75	4.92	25.970	203.31
19	35.890	1288.09	1011.66	3.90	20 594	256.89
20	31.961	1021.44	802.24	3.09	16.331	323.32
21	28.462	810.09	636.24	2.45	12.952	407.67
22	25.347	642.47	504.60	1.95	10.272	514.03
23	22.571	509.45	400.12	1.54	8.1450	648.25
24	20.100	404.01	317.31	1.22	6.4593	817.43
25	17.900	320.41	251.65	.97	5.1227	1030.71
26	15.940	254.08	199.56	.77	4.0623	1299.77
27	14.195	201.50	158.26	.61	3.2215	1638.97
28	12.641	159.80	125.50	.48	2.5548	2066.71
29	11.257	126.72	99.526	.38	2.0260	2606.13
30	10.025	100.50	78.933	.30	1.6068	3286.04
31	8.928	79.71	62.603	.24	1.2744	4143.18
32	7.950	63.20	49.639	.19	1.0105	5225.26
33	7.080	50.13	39.369	.15	.8014	6588 33
34	6.304	39.74	31.212	.12	.6354	8310.17
35	5.614	31.52	24.753	.10	.5039	10478.46
36	5.000	25.00	19.635	.08	.3997	13209.98
37	4.453	19.83	15.574	.06	.3170	16654.70
38	3.965	15.72	12.347	.05	.2513	21006.60
39	3.531	12.47	9.7923	.04	.1993	26427.83
40	3.144	9.88	7.7365	.03	.1580	33410.05

*1 mile pure copper wire 1-16 in. diam.=13.59 ohms at 15.5°C or 59.9°F.

Table of Dimensions and Resistances of Pure Copper Wire.*

REVISED.

No. B. & S.	Resistance at 75°F. R ohms per 1000 feet.	Ohms per mile.	Feet per ohm.	Ohms per pound.	lbs p. 1000 ft. ins'd H.B.&H. line wire.	Feet per lb. ins'd H.B.&H. line wire.
4-0	.04904	.25891	20392.9	.00007653	800	1.25
3-0	.06184	.32649	16172.1	.00012169	666	1.50
00	.07797	.41168	12825.4	.00019438	500	2.00
0	.09827	.51885	10176.4	.00030734	363	2.75
1	.12398	.65460	8066.0	.00048920	313	3.20
2	.15633	.82543	6396.7	.00077784	250	4.00
3	.19714	1.04090	5072.5	.0012370	200	5.00
4	.24858	1.31248	4022.9	.0019666	144	6.9
5	.31346	1.65507	3190.2	.0031273	125	8.0
6	.39528	2.08706	2529.9	.0049728	105	9.5
7	.49845	2.63184	2006.2	.0079078	87	11.5
8	.62849	3.31843	1591.1	.0125719	69	14.5
9	.79242	4.18400	1262.0	.0199853		
10	.99948	5.27726	1000.5	.0317946	50	20.0
11	1.2602	6.65357	793.56	.0505413		
12	1.5890	8.39001	629.32	.0803641	31	32.0
13	2.0037	10.5798	499.06	.127788		
14	2.5266	13.3405	395.79	.203180	22	45.0
15	3.1860	16.8223	313.87	.323079		
16	4.0176	21.2130	248.90	.513737	14	70.0
17	5.0660	26.7485	197.39	.816839		
18	6 3880	33.7285	156.54	1.298764	11	90.0
19	8.0555	42.5329	124.14	2.065312		
20	10.1584	53.6362	98.44	3.284374		
21	12.8088	67.6302	78.07	5.221775		
22	16.1504	85.2743	61.92	8.301819		
23	20.3674	107.540	49.10	13.20312		
24	25.6830	135.606	38.94	20.99405		
25	32.3833	170.984	30.88	33.37780		
26	40.8377	215.623	24.49	53.07946		
27	51.4952	271.895	19.42	84.39916		
28	64.9344	342.854	15.40	134.2 05		
29	81.8827	432.341	12.21	213.3973		
30	103.245	545.133	9.686	339.2673		
31	130.176	687.327	7.682	539.3404		
32	164.174	866.837	6.091	857.8498		
33	207.000	1092.96	4.831	1363.786		
34	261.099	1378.60	3.830	2169.776		
35	329.225	1738.31	3.037	3449.770		
36	415.047	2191.45	2.409	5482.766		
37	523.278	2762.91	1.911	8715.030		
38	660.011	3484.86	1.515	13864.51		
39	832.228	4394.16	1.202	22043.92		
40	1049.718	5542.51	.9526	35071.11		

*1 mile pure copper wire 1-16 in. diam.=13.59 ohms at 15.5°C. or 59.9°F.

TABLE OF ELECTRICAL UNITS.

UNIT OF	NAME	DERIVATION.	Dimensions in C. G. S. Units.
Electromotive force	Volt	Ampere × Ohm	10^8
Resistance	Ohm	Volt ÷ Ampere	10^9
Current	Ampere	Volt ÷ Ohm	10^1
Quantity	Coulomb	Ampere × Second	10^1
Capacity	Farad	Coulomb ÷ Volt	10^9

SIGNIFICATIONS

OF SIGNS USED IN CALCULATIONS.

$=$ signifies equality, thus $5+2=7$.

$+$ signifies addition, thus $3+2=5$.

$-$ signifies substraction, thus $8-6=2$.

$\times$ signifies multiplication, thus $5\times3=15$.

$\div$ signifies division, thus $18\div3=6$.

: :: : signifies proportion, thus 2 is to 3—

$\sqrt{}$ signifies square root thus $\sqrt{16}=4$.

$\sqrt[3]{}$ signifies cube root thus $\sqrt[3]{64}=4$.

3^2 signifies 3 is to be squared $3^2=9$.

3^3 signifies 3 is to be cubed $3^3=27$.

ELECTRICAL AND MAGNETIC UNITS.

AMPERE. — The unit of current strength. It is the flow of electricity produced by the pressure of one volt on a resistance of one ohm.

COULOMB. — The unit of electric quantity. It is the amount of electricity which flows past a given point in one second on a circuit conveying one ampere.

FARAD. — The unit of capacity A condenser that will hold one coulomb at a pressure of one volt has a capacity of one farad.

OHM. — The unit of electrical resistance. Ohm's law states that the current in any circuit is equal to the E. M. F. acting on it divided by its resistance.

VOLT. — The unit of electro-motive force or pressure analogous to the head of water in hydraulics.

WATT. — The unit of work. $\frac{1}{746}$ of a horse power, *i. e.* 746 watts equal 1 horse power. We may find the watts used in a circuit by three formulæ, thus:

WATTS = Amperes (squared) × ohms.
WATTS = Amperes × volts.
WATTS = Volts (squared) ÷ by ohms.

DYNE.—The absolute unit of force. It is that force which if it acts on one gramme for one second gives to it a velocity of one centimetre per second. In the *C. G. S. system the unit of magnetism is the force of a magnetic pole, which repels an equal pole at a distance of one centimetre with a force of one dyne.

*C. G. S.—The abbreviation o centimetre, gramme, second, and used to designate the so-called absolute system of measurement, viz.: The (Centimetre) the unit of length. The (Gramme) the unit of mass. The (Second) the unit of time.

APPENDIX C.

SOME PRACTICAL DIRECTIONS FOR ARMATURE WINDING.

An armature of a dynamo may be defined as the part in which electricity is generated. Of the three inherent conditions involved in such a structure, mechanical, magnetic and electrical, the first two usually coincide; for the iron used to complete the magnetic circuit from pole to pole of the field, also supports and drives the wire in which the electricity flows.

A Siemens "H" or shuttle armature is the simplest, and for small dynamos gives a much greater output than any other form. Such a core is shown in Figure 168. It consists of a cast or wrought iron cylinder grooved deeply on both sides. For mounting it upon a shaft, an axial hole is drilled the entire length.

Before winding such a core, the corners are to be rounded, and any roughness filed away. Amateurs are prone to pay too little attention to insulation. About three layers of tough and thin manilla paper should be shellacked on. Each layer should be allowed to become dry before putting on the next. The strips of paper should be cut differently for each layer, so that the joints will not come over each other, and in no case should a joint come over a corner of the core. Let the starting end of the wire be extra insulated with a few turns of tissue paper, well shellacked. Pass the wire along the groove, across the end, back in the other groove to the starting point; place a second

turn along side the first, and so on until one layer is complete. A little trial will show how to dodge by the shaft. Wind on other layers, pressing or hammering them tightly in place with a hard-wood stick, shellacking each in turn until the groove is completely filled. The last layer may well have several coats of shellac. Figure 169 shows a section of wound core, with the wire exaggerated in size. The two ends of the wire are to be connected to a two-part commutator.

Such an armature as this, 4 inches in length and 2 inches in diameter, with grooves $1\frac{3}{8}$x$\frac{3}{8}$ inch is the kind used in a one-quarter-horse-power dynamo. Wound with $\frac{3}{4}$-pound double cotton

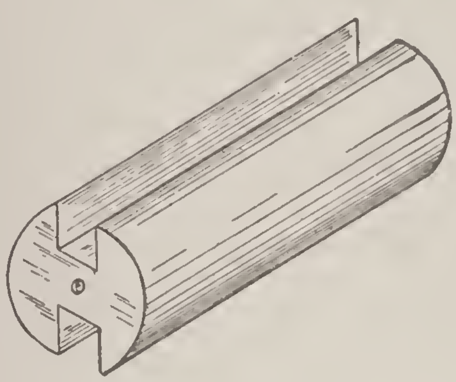


FIGURE 168.

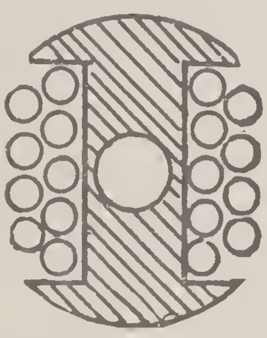


FIGURE 169.

covered No. 18 wire; about 200 turns can be put on, and the armature will give 35 volts and 6 amperes. On this as a basis, other potentials can be estimated. The electro-motive force will vary directly as the number of turns of wire; the products of the number of volts by the number of amperes; the watts will be constant, at about 200. For higher potentials it would be better to use two collector rings, and take the current alternating, as a two-segment commutator allows considerable sparking.

Sometimes the center part of the core, over which the wire is wound, is made shorter than the crescent-shaped sides. The shaft is then not in the way of the winding. Brass caps, into which short lengths of shafting are driven, are screw-

ed to the end of the core. Such a core, complete, has two lead wires to commutator brought out through the center of the shaft. It is not easy to make and keep such separate pieces in line; of all things, a shaft should be continuous.

Single coil armatures are not well adapted for motors, on account of their "dead center." Even in dynamos the action is not easy, but rather jerky, and the current is pulsating. Greater

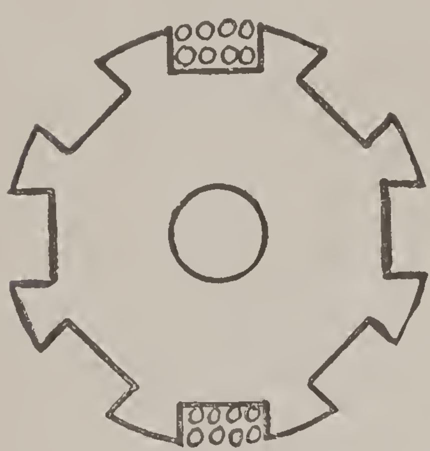


FIGURE 170.

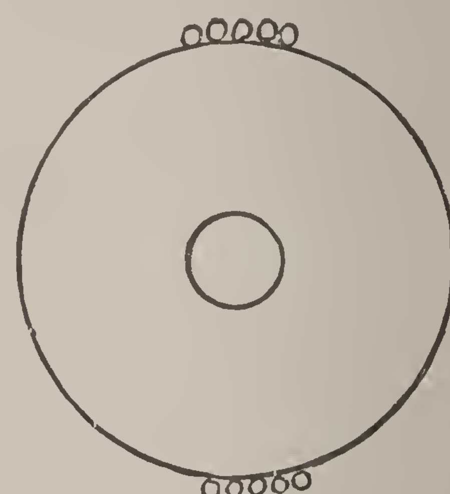


FIGURE 171.

uniformity can be attained by increasing the number of grooves for the wire, with a corresponding number of commutator segments. In Figure 170 is a core with eight grooves. Such an armature for continuous running should be built up of sheet iron, clamped tightly together by means of nuts screwed on the shaft. A core 3 inches in diameter and 6 inches long will give a full horse power. The grooves should be $\frac{5}{8}$ inch wide and $\frac{3}{8}$ inch deep. In determining the size of wire to be used on an armature, 500 circular mils should be allowed for every ampere, from 30 to 36 inches in length for every volt is necessary.

Suppose it is desired to wind the armature just described for 110 volts. Allowing the working efficiency to be 75 per

cent., the current at one-horse power will be about 9 amperes. As only one-half the current is found in any one wire, a suitable size for $4\frac{1}{2}$ amperes must be chosen. No. 17 is the nearest that can be found in the wire tables. After insulating the grooves thoroughly, there should be room for 10 turns per layer, and six layers. Each section is to be wound 3 layers deep for the first round, leaving out loops at the beginning of each coil for connection to one half of the commutator. For the second round, 3 layers on top of the others will give loops for the last half of the commutator. This is a simple multiple winding, similar to that referred to in the following paragraph.

Any sort of projection from an armature core, between the coils, is a source of heating. As the edges of the core and pole piece pass, eddy currents are produced. It has been common to dispense with all projections, and wind the wire over the entire smooth surface of the cores. Figure 171 shows a coil in position on such core. Figure 172 gives a perspective of the same, showing also the fibre pegs that keep the winding in place. In Figure 173, the whole winding is complete with the binding wires on.

Siemens drum armatures, such as have been described, are of comparatively small diameter and need to be revolved at light speed in order to give the necessary peripheral velocity. Gramme ring armatures have a larger external diameter, the center portion being cut away, as shown in Figure 174. Notches cut in the internal circumference allow the arms of the "spider" to catch hold and attach the core to the shaft.

The winding is in and out around the ring. One coil can be seen in position in Figure 175. In order to get the wire closely into the space allotted for each coil, it is necessary to

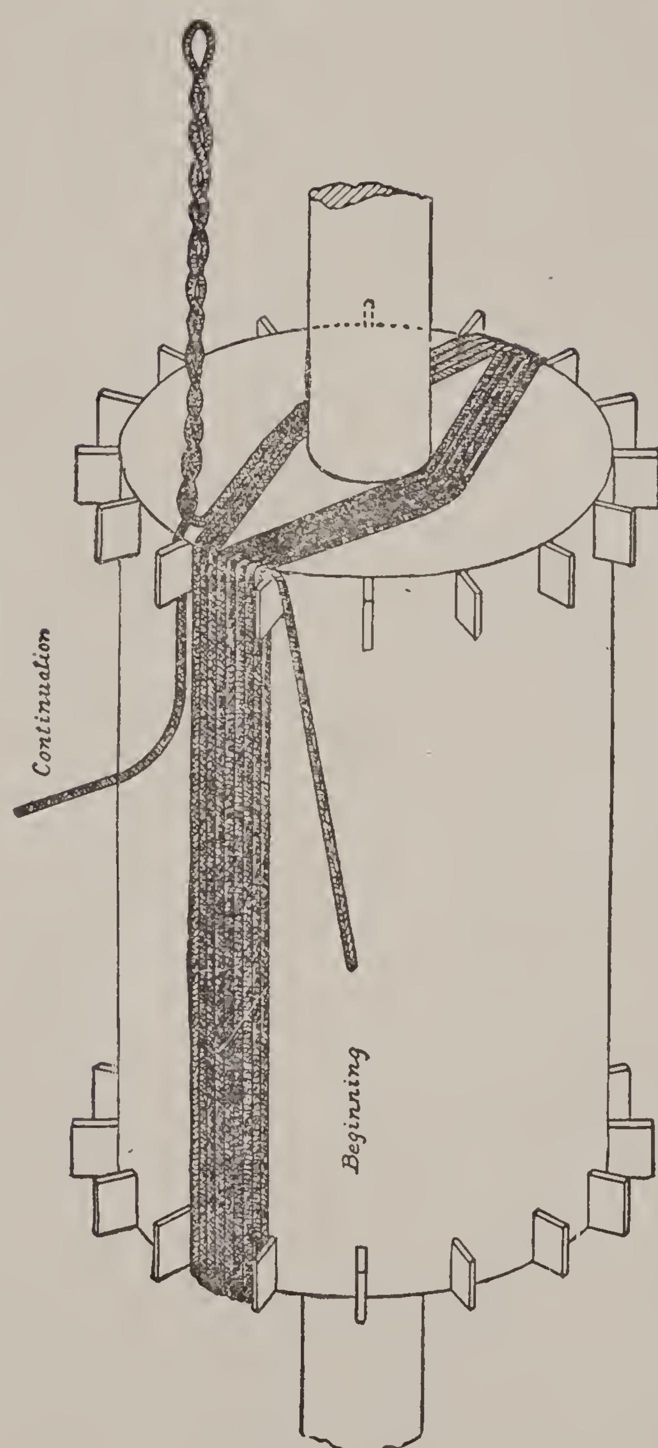


FIGURE 172.

lay the wires in twice as many layers on the inside as on the outside. After insulating the core, it is well to mark on the insulation the space for each coil, then there will be no chance

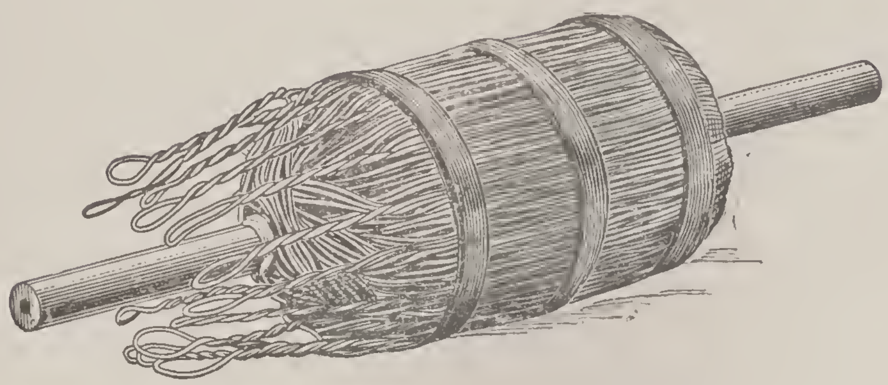


FIGURE 173.

to come out uneven. A core 7 inches outside diameter, $4\frac{1}{2}$ inside and $4\frac{1}{2}$ inches axial length is suitable for a two-horse power machine. For 110 volts put on No. 14 wire, three (on the outside) layers deep. The number of sections into which the

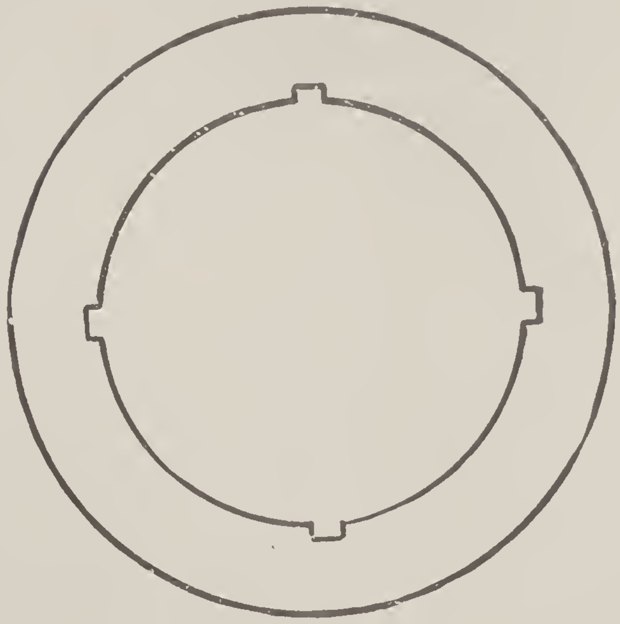


FIGURE 174.

winding and commutator is divided, depends on the voltage of the dynamo or motor, 10 volts between adjacent segments insures good working, 15 volts and over occasions sparking. For 110

volts the whole difference of potential between the brushes will be at points half way around the commutator. Allowing 10 volts per segment there will be 11 segments; however, it would be well to make the commutator with an even 24 segments on account of ease in dividing the coils equally between the arms of the spider.

A drum armature may be completely wound without making a cut in the wire. With a ring armature, the necessity of pass-

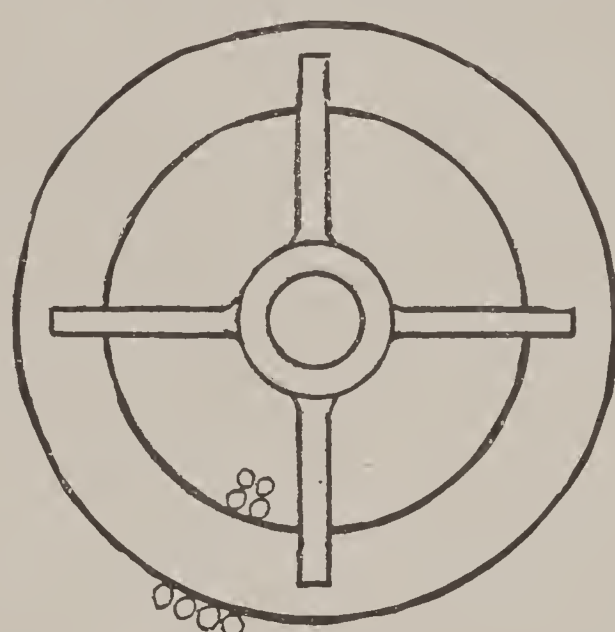


FIGURE 175.

ing the wire in and out through a small space compels each coil to be wound up of wire cut to the right length. This length can be roughly determined by winding the right number of turns with a cord and using the cord as a measure. The beginning of each coil should be marked in one color, and the end with another. Then with all the coils wound in the same direction, the beginning of one coil is to be connected to the end of the preceding, and a lead wire from the junction run to a commutator segment, or the two wires themselves may be soldered to the same segment. The winding becomes a contin-

uous path with taps at equidistant points leading to the commutator. A drum armature must have its winding specially adapted to the number of poles of the field magnets. Usually the fields have but two poles and the winding is as described. A four or six pole winding is very awkward and very seldom used in small machines. A ring armature is capable of running in a

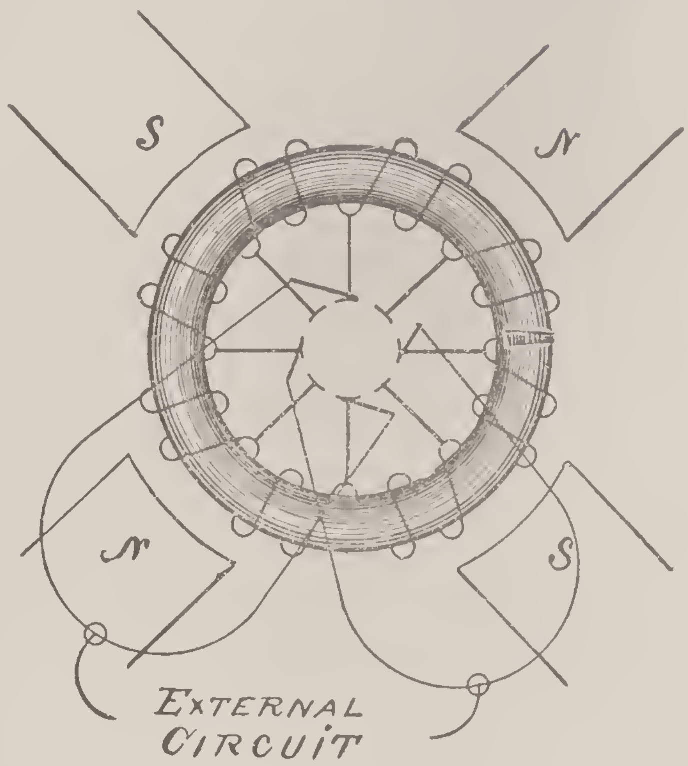


FIGURE 176.

field with any number of poles. Figure 176 shows a four-pole field. The whole potential of the dynamo is then generated in the coils 90° apart. The brushes opposite to each other are connected in multiple. By connecting opposite coils of the armature together by means of a common lead to commutator segments, only two sets of brushes are necessary, these to be 90° apart.

There is this advantage in a multipolar field, that the wire is in action oftener and hence slower speeds are allowable than can be efficiently produced with bipolar fields.

APPENDIX D.

FIELD MAGNET WINDING.

(FIELD FORMULÆ.)

The calculations for the strength of the field, and the necessary current to produce it, are based upon the assumption that the lines of magnetic force obey a similar law to that for electric current, viz.; that they vary directly as the magnetizing force and inversely as the resistance of the circuit. Kapp has made this a subject of investigation and finds a formula which fits approximately to observed facts. This is given below:

$$Z = \frac{P}{1440\frac{2d}{cb} + \frac{l}{ab} + \frac{2\,L}{AB}}$$

and

$$Z = \frac{0.8\ P}{1800\frac{2d}{bc} + \frac{l}{ab} + \frac{3\,L}{AB}}$$

Where $Z =$ the total number of lines of force, P the exciting power in ampere-turns, a b the cross section of the armature (Gramme ring in this case), c the arc spanned by each pole piece, d the distance between the polar surface of the magnets and the external surface of the armature core, l the average length of the magnetic circuit inside the armature, L the length of the magnetic circuit in the field magnets, and A B the cross sectional area of their core. See Figure 177.

As the lengths are all given in inches, the exciting power in ampere turns, and the result Z in the same units chosen in

the armature formula, viz.: 6000 times larger than the absolute unit, so that the results obtained by this formula may be readily applied to the armature calculations.

The first of the two formulae is for well annealed wrought iron, and a wrought iron armature core, the second is best for

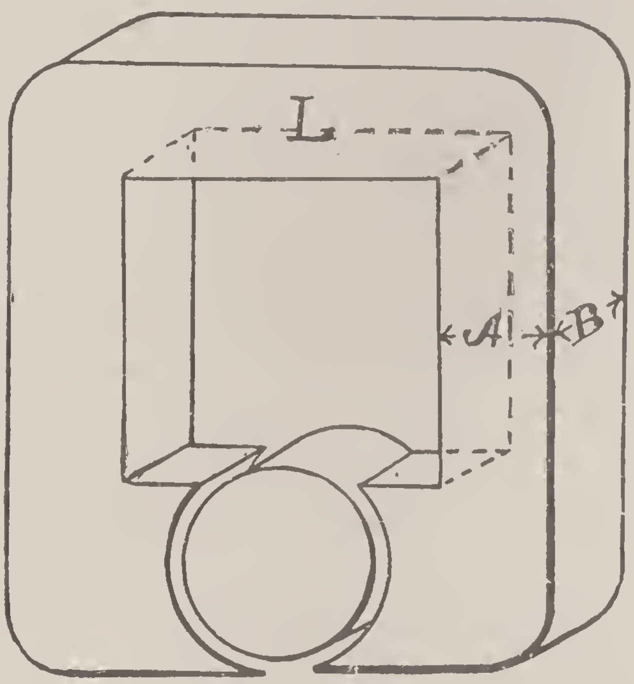


FIGURE 177.

cast iron magnets. The formulae only apply where the degree of magnetization of the field core is not higher than ten lines per square inch, and they give pretty fair results. Higher degrees of magnetization demand more current than the formulae call for, and when the saturation point is approached, the increased power necessary over that given in the formulae is from 40 to 100 per cent.

Different specimens of iron will sometimes vary in their magnetic qualities, to such an extent that a formula will often not serve a much better purpose than a foundation upon which to base a good guess. The formulae of Kapp however are about the best that have been brought out as yet, and are near

enough to the truth to enable one to build a dynamo, and not come very far from the calculated output. By multiplying the Z by the denominator of the fraction in the second term we

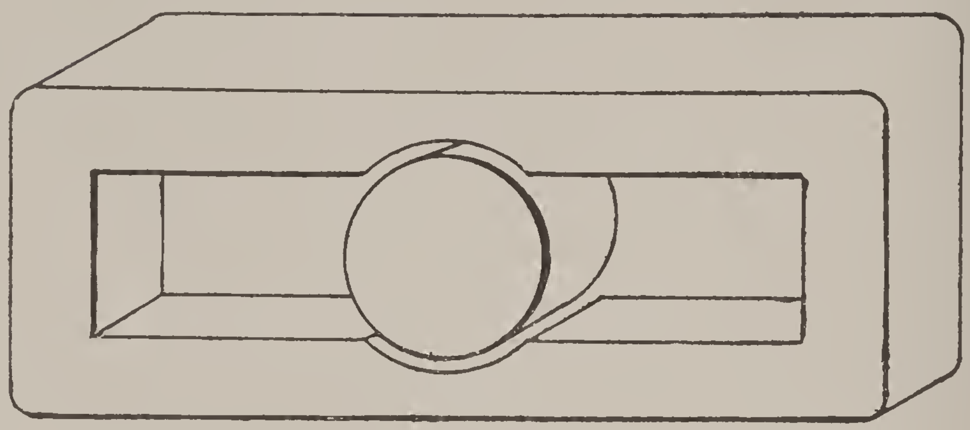


FIGURE 178.

get the value of P or the ampere-turns which we must use upon our magnets. The formulae where double magnets are used, are

$$\frac{Z}{2} = \frac{P}{1440\frac{2d}{bc} + \frac{2l}{ab} + \frac{2L}{AB}}$$

for wrought iron and for cast iron

$$\frac{Z}{2} = \frac{0.8\ P}{1800\frac{2d}{bc} + \frac{2l}{ab} + \frac{3L}{AB}}$$

The double field magnet can be made lighter than the single one for the same power, but requires more copper. Where expense is an item to be considered it must give way to the single magnet, but where weight is the chief point, it is to be preferred. See Figure 178.

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